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SURVIVAL OF HATCHERY SUBYEARLING FALL CHINOOK SALMON IN THE FREE-FLOWING SNAKE RIVER AND LOWER SNAKE RIVER RESERVOIRS, 1998-2001

Summary Report 1998-2001

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Survival of Hatchery Subyearling Fall Chinook Salmon in the Free-Flowing Snake River and Lower Snake River Reservoirs, 1998-2001

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EXECUTIVE SUMMARY

We report results from four years (1998-2001) of an ongoing study of survival and travel time of subyearling fall chinook salmon in the Snake River. We report analyses of associations among river conditions and survival and travel time estimates, which include data from 1995 through 1997. At weekly intervals from early June to early July each year (mid-May to late June in 2001), hatchery-reared subyearling fall chinook salmon were PIT tagged at Lyons Ferry Hatchery, trucked upstream, acclimated, and released above Lower Granite Dam at Pittsburg Landing and Billy Creek on the Snake River and at Big Canyon Creek on the Clearwater River. Each year, a small proportion of fish released were not detected until the following spring. However, the number that overwintered in the river and migrated seaward as yearlings the following spring was small and had minimal effect on survival estimates. Concurrent with our studies, a number of subyearling fall chinook salmon that reared naturally in the Snake River were caught by beach seine, PIT tagged, and released. We compared a number of characteristics of hatchery and wild fish. Hatchery and wild fish were similar in 2001, and from 1995 through 1997. Results for 1998 through 2000 showed some relatively large differences between hatchery and wild fish. However, recent information suggests that a considerable proportion of wild subyearling chinook salmon migrating in a given year may actually be stream-type (spring/summer), rather than ocean-type (fall) fish, which may account for some of the differences we have observed.

For groups of hatchery fish released from 1995 through 2001, survival estimates from release to the tailrace of Lower Granite Dam were correlated with release date each year (later release groups had lower survival). From 1995 through 2000, estimated survival probabilities typically ranged from a high of 45 to 65% for the earliest releases down to a low of 5 to 10% for the latest. In the extremely low-flow conditions of 2001, the greatest survival probability estimates for Billy Creek and Pittsburg Landing release groups were 41% and 11%, respectively. For the latest release groups in 2001, estimated survival was less than 1%. Data on timing of arrival at Lower Granite Dam suggest that the trend in survival estimates was not the result of differing “readiness to migrate” or other physiological aspects of fish in successive release groups. Estimated survival to Lower Granite Dam and release date were also significantly correlated with three environmental variables: flow, water temperature, and turbidity. Survival decreased as flow volume and turbidity decreased (water clarity increased) and water temperature increased. Because of strong correlations among the environmental variables, it is not possible to determine unequivocally which variable had greatest influence on survival.

Additionally, in 1999, 2000, and 2001, we collected run-of-river subyearling chinook salmon (mostly wild fish from the Hanford Reach) at McNary Dam, PIT tagged them, and released them. In 2000, estimated survival to John Day Dam was just as high for fish released in the gatewell of McNary Dam as for those released in the tailrace, though the estimate had low precision because of low detection rates at John Day Dam. Estimated survival from the tailrace of McNary Dam to the tailrace of John Day Dam was 0.744 (s.e. 0.205) in 2000 and 0.581 (s.e. 0.016) in 2001.

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INTRODUCTION

Much is unknown about migrational characteristics of Snake River subyearling fall chinook salmon *Oncorhynchus tshawytscha,* including the proportion that survive passage through the Snake River dams and reservoirs, how flow volume and water temperature affect survival, and the percentage of migrants collected and transported at the dams. As a result, operational strategies to maximize survival in the Snake River have been largely based on data from studies of subyearling chinook salmon in the lower Columbia River. The Snake River fall chinook salmon ESU (evolutionarily significant unit) was listed as threatened under the Endangered Species Act in April 1992 (NMFS 1992). Information specific to Snake River migrants is necessary to develop and assess the effects of possible restoration strategies such as supplementation, transportation of smolts, dam modification, dam breaching, flow augmentation, spill, or reservoir drawdown.

Because of the low population size of the listed stock, conducting research with wild subyearling fall chinook salmon has been difficult. Initial studies by Connor et al. (1998) and Connor (2001) using wild fish collected, PIT tagged, and released in the free-flowing Snake River above Lower Granite Dam found that survival decreased coincidental in time with decreases in flow, increases in water temperature, and decreases in turbidity. The ability to determine temporal trends within seasons was limited by the number of fish available for tagging, particularly late in the migration season (late June and early July), when few fish remain in the free-flowing Snake River.

To overcome this problem, we used subyearling fall chinook salmon raised at Lyons Ferry Hatchery as surrogates for wild fish, ensuring that we could release sufficient fish in each group, even late in the migration season. Starting in 1995, we estimated survival and travel time using subyearling chinook salmon reared at Lyons Ferry Hatchery, PIT tagged at the hatchery, and transported upstream for release in the free-flowing Snake and Clearwater Rivers above Lower Granite Dam (Muir et al. 1998, 1999; Smith et al. 1997). Here we report results from releases of PIT-tagged hatchery subyearling fall chinook salmon over four years (1998-2001) in the Snake River and two years (1998-1999) in the Clearwater River. Study objectives were to 1) estimate detection and passage survival probabilities of hatchery subyearling fall chinook salmon released in the Snake and Clearwater Rivers, and 2) investigate relationships among travel times and passage survival probabilities and environmental influences, including flow volume, water temperature, and turbidity. For the second objective, we used data from releases in 1995 through 1997 in addition to data from the 1998 to 2001 releases.

In addition to the ongoing Snake River survival study, we report complete results of survival studies conducted at McNary Dam in 2000 and 2001. River-run subyearling fall chinook salmon were collected at McNary Dam (most originated in the Hanford Reach), PIT tagged, and released to estimate survival through the juvenile collection/bypass system. We also estimated survival and travel time from the tailrace of McNary Dam to the tailrace of John Day Dam.

METHODS

Study Area

Subyearling fall chinook salmon were PIT tagged at Lyons Ferry Hatchery (Snake River Kilometer (RKm) 95), operated by Washington Department of Fish and Wildlife. PIT-tagged fish were released at Asotin, Billy Creek, and Pittsburg Landing on the Snake River (RKm 236, 265, and 346, respectively) and at Big Canyon Creek on the Clearwater River (Clearwater RKm 57). Tagged fish were detected at dams during their downstream migration to Bonneville Dam, the last dam on the Columbia River (Columbia RKm 234)(Fig. 1). The study area included a 111-km free-flowing reach of the Snake River, a 57-km free-flowing reach of the Clearwater River (confluence at Snake RKm 224), and eight dams and reservoirs. Six of these dams were equipped with PIT-tag detection systems (Prentice et al. 1990): Lower Granite Dam (Snake RKm 173), Little Goose Dam (Snake RKm 113), Lower Monumental Dam (Snake RKm 67), McNary Dam (Columbia RKm 470), John Day Dam (Columbia RKm 347), and Bonneville Dam. The Snake River enters the Columbia River at Columbia RKm 522.

Release Groups above Lower Granite Dam

Snake River fall chinook salmon exhibit an ocean-type life history (Healey 1991); most migrate to the ocean as subyearlings. Our goal was to release experimental (hatchery-reared) fish of approximately the same size as wild fall chinook salmon present in the Snake River at the time of release. Target size for fish each year was 75 mm in fork length. The migration of wild subyearling chinook salmon from rearing areas upstream of Lower Granite Dam varies annually and occurs over a protracted period (Connor et al. 2002). Smolt passage at Lower Granite Dam typically begins in late May and continues through late summer and fall (Connor et al. 2002). Therefore, we made a series of releases each year, typically on six dates between the first week of June and the second week of July. These release dates covered the migration period of wild subyearling fall chinook salmon in all present-day fall chinook salmon production areas in the Snake River basin.

Fish for release groups were PIT tagged at Lyons Ferry Hatchery each week, using standard techniques (Muir et al. 1999). At the hatchery, well water was supplied during tagging and loading for transportation at a near constant temperature averaging 12°C. Fork lengths of all fish tagged were measured, and about 10% of the fish were weighed. Immediately after PIT tagging, we transported fish in truck-mounted aerated tanks (approximately 1,000 L) to release sites at Asotin (1999), Billy Creek (1998, 2000, 2001), and Pittsburg Landing (1998-2001) on the Snake River, and at Big Canyon Creek (1998 and 1999) on the Clearwater River (Table 1). Holding densities in the transport vehicles were kept below 8 kg fish/m^3 of water. At the release sites, fish were acclimated to ambient river temperatures (no more than 2°C warming per hour) using a gasoline-powered water pump that gradually replaced the hatchery water in the tank with river water. After acclimation, fish were released directly into the Snake and Clearwater Rivers via flexible hose.

Release Groups at Lower Granite Dam

To study migrational characteristics downstream from Lower Granite Dam, we used PIT-tagged subyearling fall chinook salmon that were detected in the juvenile fish collection facility at Lower Granite Dam and returned to the tailrace. These included fish from our release groups for this study, release groups of Lyons Ferry Hatchery fish in the Snake and Clearwater Rivers for other experiments of ours and in the Clearwater River for experiments by the Nez Perce Tribe, and release groups of wild fish captured by beach seine in the Snake River, tagged, and released by the U.S. Fish and Wildlife Service. Fish were grouped by week of detection at Lower Granite Dam. Thus, each group consisted of actively migrating fish "released" below Lower Granite Dam within the same 7-day period (a small percentage of fish that pass Lower Granite Dam might continue to rear in Little Goose Reservoir for a period of time). We estimated the survival probability from Lower Granite Dam tailrace to Lower Monumental Dam tailrace for 13 to 17 weekly groups each year from 1998 to 2001 (Table 2). For most weekly groups, data were not sufficient to estimate survival probabilities beyond Lower Monumental Dam.

PIT-Tag Interrogation and Slide-Gate Systems

At each dam, fish pass either via spillways or via the powerhouse. Diversion screen systems are installed in turbine intakes so that fish entering the powerhouse are guided away from turbines and into bypass channels. Fish passing via spillway or not guided away from turbines are not monitored for PIT tags. Monitoring equipment (Prentice et al. 1990) detected PIT-tagged fish that passed through fish bypass systems (Matthews et al. 1997) at Lower Granite, Little Goose, Lower Monumental, McNary, John Day, and Bonneville Dams (Fig. 1). Slide gates in the bypass systems automatically diverted most detected PIT-tagged fish back to the river (Marsh et al. 1999), allowing multiple detections of individual tagged fish. Fish bypass and PIT-tag interrogation commenced each year in late March or early April. The time period of fish bypass operation and PIT-tag monitoring varied by dam and year. Fish bypass and PIT-tag monitoring typically began in early July and ended at all dams by early December. In 1999, interrogation ended on 31 August at Snake River dams and in mid-October at McNary Dam. We retrieved the PIT-tag detection data from the PIT Tag Information System (PTAGIS), a regional data base (PSMFC 1996).

Data Analyses

We used the methods described by Skalski et al. (1998) and Muir et al. (2001a) for data collection and retrieval from PTAGIS, database quality assurance/control, construction of detection histories, tests of assumptions, estimation of detection and survival probabilities, and travel time. The Single-Release Model (SR) was used to estimate survival from PIT-tag detection history data (Cormack 1964, Jolly 1965, Seber 1965, Skalski et al. 1998, Muir et al. 2001a,b). For the last release group from Billy Creek and the last three from Pittsburg Landing in late 2001, detections were not sufficient to use the SR Model to estimate survival. For these groups, we used the following methods developed for migrating smolts by Sandford and Smith (2002): Using data from all groups pooled, we estimated average detection probability at Lower Granite Dam for each day of the migration season. We then used these estimates to expand daily detection numbers to estimate the total number of fish that passed the dam from each of the four late release groups. Survival estimates were calculated as the estimated total number passing the dam divided by the number released.

Overwintering and Interpretation of Model Parameters

A small percentage of Snake River fall chinook salmon do not migrate in their year of emergence. Instead, they overwinter in the Snake River and resume migration as yearlings the following spring. This tendency leads to violation of assumptions of the SR Model. Fish released in the Snake and Clearwater Rivers that immediately migrated downstream would be expected to have higher survival probabilities than would fish that were released at the same time but spent the winter in the reservoir prior to migrating the following spring.

Because of the effects that overwintering fish might have on survival estimates, we based our survival analyses solely on PIT-tag detections that occurred during the summer and fall following release, and ignored detections that occurred the following spring. This approach changed the interpretation of survival probabilities in the SR Model. For example, the parameter usually defined as the probability of survival within a particular reach (Skalski et al. 1998, Muir et al. 2001a), became the combined probability of migrating through the reach as a subyearling and the probability of surviving the reach for subyearling migrants (i.e., the product of the two probabilities). The detection probability at each dam was the probability for individuals that migrated as subyearlings, not for the entire group.

We estimated the proportion of study fish that overwintered each year, based on the proportion that were detected the following spring and on detection probabilities for fall chinook salmon reared to yearling stage at Lyons Ferry Hatchery, PIT tagged, and released in the Snake River as yearlings each spring. (We could not reliably estimate these probabilities based on our fish that migrated in the spring after overwintering in the river because too few of them were detected in the spring each year).

Travel Time and Migration Rate

After release above Lower Granite Dam, subyearling fish from Lyons Ferry Hatchery (and wild fish of comparable physiological status) spend up to several weeks feeding and growing until they are of sufficient size and physiologically ready to begin active seaward migration. We refer to the time between release and arrival at Lower Granite Dam as "travel time," while remembering that a significant portion of that time is spent rearing or dispersing downstream passively, rather than actively migrating seaward (Connor et al. in press[a]).

We used travel time and migration rate as measures of seaward movement. For each fish detected at Lower Granite Dam, travel time was calculated as the number of days between release and the first detection at the dam. Between any two dams, travel time for each fish detected at both dams was calculated as the number of days between last detection at the upstream dam and first detection at the downstream dam. For each reach-specific travel time, we calculated the corresponding migration rate (km/day).

We calculated travel time and migration rate statistics for the following river stretches: 1) Pittsburg Landing to Lower Granite Dam (173 km); 2) Big Canyon Creek to Lower Granite Dam (108 km); 3) Billy Creek to Lower Granite Dam (92 km); 4) Asotin to Lower Granite Dam (63 km), 5) Lower Granite Dam to Little Goose Dam (60 km); 6) Little Goose Dam to Lower Monumental Dam (46 km); 7) Lower Monumental Dam to McNary Dam (119 km), and 5) release to McNary Dam.

For each release group, we compiled the distributions of individual-fish travel times and migration rates. We report the minimum, 20th percentile, median, 80th percentile, and maximum of the distributions for each release group. The true, complete set of travel times for a release group includes travel times of both detected and undetected fish. However, travel times cannot be determined for PIT-tagged fish that traverse a river section but are not detected at both ends of the section. Travel time statistics are computed only from travel times of detected fish, presenting a sample of the complete set.

Comparison of Wild and Hatchery Subyearling Fall Chinook Salmon

To compare characteristics of hatchery fish in our release groups with those of wild fish present in the river, we used a beach seine to capture wild subyearling chinook salmon in the Snake River from April to July each year (Connor et al. 1998). Wild fish were PIT tagged where they were captured (between Snake RKm 225 and 366), then released to resume rearing and seaward migration. Wild fish captured upstream from the confluence with the Salmon River (Snake RKm 303) were most similar in release timing and location to the earliest release groups of hatchery fish from Pittsburg Landing. Wild fish captured below the confluence with the Grande Ronde River (Snake RKm 273) were most similar in timing and location to the earliest release groups from Billy Creek and Asotin. We compared the following characteristics of wild and hatchery subyearling chinook salmon: fork length at release; travel time to Lower Granite Dam; date of passage at Lower Granite Dam; and survival to the tailrace of Lower Granite Dam.

River Conditions Associated with Survival and Travel Time, 1995-2001

For groups released at Pittsburg Landing and Billy Creek from 1995 to 2001, we used various graphical methods and simple and multiple linear regression modeling to explore relations among indices of exposure to selected environmental factors and survival and travel time. Because the independent variables were correlated with each other, and because some relations had notable nonlinearity, we evaluated multiple regression models using the generalized additive model ("gam") function of the statistical software package S-Plus (MathSoft, Inc. 2000). The nonparametric splines ("partial fits") calculated in the gam function were used to suggest parametric curve functions (polynomials and sigmoidals, primarily) to use in parametric multiple regression models. Resulting multiple regression models were rejected if graphic inspection of residuals revealed remaining nonlinearity or notable lack of normality.

For a subyearling fall chinook salmon released in the free-flowing Snake River, the period between release and arrival at Lower Granite Dam was divided between rearing and active, directed seaward migration. The survival probability from release to Lower Granite Dam was the joint probability of surviving the rearing period and of surviving the migration period. River conditions likely affected fish survival and travel time differently depending upon whether they were rearing or migrating. While PIT-tag detection data gave information on the total days until arrival at the dam, they could not precisely divide the time between rearing and migration. Moreover, timing of onset of migration and migration rates varied among individuals, while release-recapture data allowed survival estimation only at the group level.

Thus, to investigate relations with survival, we needed quantitative indices of exposure to river conditions, defined at the group level, and focused to the extent possible on either the rearing or the migration period exclusively. Accordingly, for each release group, we defined the "rearing index" period as the time between release and the time of the 5th percentile of passage at Lower Granite Dam. We defined the "migration index" period as the time between the 5th and 50th (median) percentiles of passage.

From the Columbia Basin Research group of the University of Washington School of Fisheries (DART 1995), we obtained the mean daily value of three characteristics of river flow at each dam in the index reach: total flow rate (kcfs), water temperature (^{o}C), and turbidity (Secchi disk). Another variable considered was release date, expressed as the ordinal day of the year, or "Julian date" (e.g., 1 June = 152 and 15 July = 196 in a non-leap year). Release date may be a surrogate variable if there are differences in physiological development between groups of fish released at different times during the migration season, or if there are other seasonal trends that are not characterized by other variables.

Indices of exposure for each group were defined as the averages of daily values of the three river condition variables during each index period. Exposure indices for the rearing index period included flow rate (RFLOW), temperature (RTEMP), and turbidity (RTURB). Corresponding indices for the migration period were MFLOW, MTEMP, MTURB. Additional variables included the duration (days) of the rearing (RTIME) and migration (MTIME) index periods; the total time between release and 50th percentile of distributions of detections at Lower Granite Dam (TTIME); the release date (Julian date) (DATE); and the estimated probability of survival between the release site and the tailrace of Lower Granite Dam (SURV).

The choice of 5th and 50th percentiles as the exact cutoff dates for rearing and migration periods was somewhat arbitrary. Clearly, the period of migration extends beyond the date of median passage at Lower Granite Dam. Our objective was to define one period when most fish in the group were rearing and another period when most fish in the group were actively migrating. When we explored the use of later dates for the end of the migration index period (e.g., date of 80^{th} percentile passage) the resulting values were very highly correlated ($r^2 > 0.95$) with indices that resulted when the 50^{th} percentile was used.

Because weekly groups of fish detected and returned to the river at Lower Granite Dam were composed mostly of actively migrating fish (c.f., Connor et al. in press[a]), consideration of rearing periods was not required. For each weekly group, we calculated indices of exposure to each environmental variable, based on the group's distribution of PIT-tag detections at Lower Monumental Dam. We first calculated the dates on which the 25th and 75th percentiles of the group's distribution of detections occurred. Indices of exposure were calculated as means of the daily measurements of the respective variables at Lower Monumental Dam during the period between the 25th and 75th percentiles of the detection distribution. The variables in this portion of the analysis included indices of flow rate (FLOW), temperature (TEMP), and turbidity (TURB); median travel time (TTIME); and the estimated probability of survival between Lower Granite and Lower Monumental Dams (SURV). For weekly groups, DATE was calculated as the average "release" date (e.g., 15-21 June = 169).

When it appeared that a sigmoidal function would fit the data, we used the following equation form ("Boltzmann sigmoid"):

$$Y = Bottom + \frac{(Top - Bottom)}{1 + e^{(V50 - X)/Slope}}$$

where *X* and *Y* were the independent and dependent variable, respectively, and *Top*, *Bottom*, *V50*, and *Slope* were parameters to be estimated. A sigmoid curve is "S-shaped:" assuming positive *Slope*, the curve rises from low to high values of *X* and *Y*, with relatively shallow slope at low and high ends of the range of *X* values, and steeper slope in the intermediate range. The *Bottom* and *Top* parameters are the minimum and maximum *Y*-values on the curve, respectively. The *V50* parameter is the *X* value for which *Y* is halfway between *Bottom* and *Top*, and *Slope* describes the steepness of the curve, with larger values denoting a shallower curve. In our models for estimated survival, the *Bottom* parameter was always set equal to 0.0 (when the parameter was estimated, it was never significantly different from 0).

Because of concomitant temporal trends in river conditions, exposure indices for release groups of PIT-tagged fish were highly correlated with each other and with release date.

Correlation of such magnitude among predictor variables generally makes it very difficult for multivariate statistical methods to distinguish the relative importance of the predictors' influence on the response variable. Nonetheless, we explored bivariate patterns, and used multivariate methods to shed light on relations. Samples were of sufficient size that correlations with relatively little explanatory power (i.e., $r^2 < 0.10$) were statistically significant ($P < 0.05$). One response to this is to lower the level required to declare a correlation significant. Our approach, however, was simply to focus on the amount of variability in the response variable that is "explained" by variability in the predictor (i.e., the r^2 value).

In all regression models of data from multiple years, including generalized additive models, we used variables for "year effects" to account for differences in annual mean survival and travel time not captured by the environmental variables. In addition, we tested for statistical significance of differences among regression coefficients for different years in both linear and nonlinear models using the "lsfit" and "nls" functions of S-Plus (MathSoft, Inc. 2000), respectively.

Release Groups at McNary Dam, 2000

To evaluate survival through the collection/bypass system at McNary Dam (including outfall), we made a series of paired releases of PIT-tagged subyearling fall chinook salmon between 19 June and 19 July 2000. Subyearling fall chinook salmon were collected at the McNary Dam juvenile collection system, sorted by Smolt Monitoring Program staff, and PIT tagged. Most fish tagged were wild fish from the Hanford Reach, though origin could not be determined for every individual because not all hatchery fall chinook salmon were fin-clipped. To minimize handling biases, fish for both release groups were tagged simultaneously and personnel were rotated between tagging stations when half of each release group was tagged. Fish handling methods such as water-to-water transfers and pre-anesthesia were used to minimize stress to fish during the sorting and tagging process. Tagged fish were transferred through a water-filled pipe to 712-L tanks mounted on trucks. While holding fish, tanks were aerated and supplied with flow-through water. Fish were held for a minimum of 24 hours for recovery and determination of post-tagging mortality.

Fish were released in two locations at McNary Dam: 1) in a gatewell (bypass groups), and 2) downstream within 1 km of the dam (tailrace reference groups)(Fig. 2). We released 14 replicate paired groups of subyearling fall chinook salmon. Bypass groups were released through a 10.2-cm diameter hose that was 27.4-m in length. The hose was tethered so that fish entered the center of the gatewell (8A), about 1 m below the surface. Bypass groups were released between 0700 and 0800 PST. Number of fish per bypass group ranged from 1,630 to 1,984.

Fish released in the tailrace were trucked downstream to the Umatilla Marina, transferred via 10.2-cm hose to a partially filled 712-L tank mounted on a barge, then transported upstream to within 1 km of the bypass outfall for release. Fish released in the gatewell were generally delayed in the bypass system. So that paired groups would mix below the dam, tailrace groups were released about 5 hours after the bypass groups (between 1145 and 1340 PST). Number of fish per tailrace group ranged from 1,386 to 1,763.

For each release group in a pair, survival to John Day Dam was estimated independently using the SR model. Detection rates were low in 2000 at John Day and Bonneville Dams, leading to imprecise survival estimates from the SR Model for individual groups. In an attempt to compensate, we pooled groups weekly and estimated survival for the paired weekly pooled groups. Three individual release groups were pooled for each of the four weeks 19-25 June, 26 June-2 July, 3-9 July, and 10-16 July. Two groups were pooled for the week of 17-23 July. For the daily and weekly series of survival estimates, we calculated overall average survival to John Day Dam using the weighted arithmetic mean of individual survival estimates, with weights equal to respective relative variance.

Five estimates of survival through the bypass system at McNary Dam were obtained by dividing the estimated survival to John Day Dam for each weekly bypass group by the estimated survival for the corresponding weekly tailrace group. Bypass survival estimates were averaged using the weighted geometric mean of the weekly estimates, with weights equal to respective relative variance.

Release Groups at McNary Dam, 2001

To evaluate survival from McNary Dam tailrace to John Day Dam tailrace, we released a series of 15 single groups of PIT-tagged subyearling fall chinook salmon into the tailrace of McNary Dam between 20 June and 28 July 2001 (Fig. 2). Collection, tagging, and release procedures were the same as for tailrace releases in 2000. The number of fish per tailrace group ranged from 1,380 to 4,285; the total was 38,546. For each release group, survival to John Day tailrace was estimated independently using the SR model.

Survival Between McNary and John Day Dams, 1998-2001

Survival estimates between McNary and John Day Dams discussed here and survival estimates from wild fish PIT tagged in the Hanford Reach in 1998 were compiled with means of flow, temperature, and turbidity measured at McNary Dam during the period the study fish were migrating through John Day Dam pool.

RESULTS

Release Groups at and above Lower Granite Dam

Subyearling fall chinook salmon PIT-tagged at Lyons Ferry Hatchery and released above Lower Granite Dam totaled 35,643 fish in 1998, 22,382 fish in 1999, 14,866 fish in 2000, and 14,962 fish in 2001 (Table 1). Mortality during handling, tagging, and transport averaged less than 2.0% for these releases.[1] Each year, PIT-tagged fish were detected at Lower Granite Dam from mid- to late May until the detection system was turned off at the end of October (system shutdown occurred earlier in 1999 for installation of new equipment). Total numbers of PIT-tagged subyearling fall chinook salmon detected at Lower Granite Dam and returned to the tailrace were 20,330 in 1998, 6,123 in 1999, 3,451 in 2000, and 11,449 in 2001 (Table 2).

Tests of Model Assumptions

Tests of assumptions showed a few more significant ($\alpha < 0.10$) violations than we would expect by chance (Tables 3 and 4). In general, however, detected and nondetected fish at a particular dam were mixed as they passed dams farther downstream, and detection history at upper dams did not affect probabilities of survival or detection at downstream dams. Further research is needed to investigate the causes of assumption violations, their effects on accuracy of survival estimates, and potential remedial measures. Given current knowledge of these issues, we believe that little bias was introduced from violations of assumptions. Results regarding annual means and relations with environmental factors were little changed if groups with significant violations were omitted. We report estimates from the SR Model for all release groups

Detection and Survival Probabilities

Detection probabilities were generally higher at Lower Granite and Little Goose Dams (equipped with extended bar screens) than at Lower Monumental Dam (Table 5). There were no apparent seasonal differences in detection probabilities. This was not unexpected, as conditions at dams, especially the absence of spill, tend to be relatively constant during the summer months. Detection probabilities were similar for groups released on the same day at different release locations, except that in 2000 and 2001 groups released at Billy Creek consistently had a higher detection probability at Lower Granite Dam than groups released on the same day at Pittsburg Landing (Table 5).

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[1] A planned 7 July 1998 release from Pittsburg Landing (1,250 fish) was lost because of a malfunctioning valve in the transport truck.

For all release sites, survival to Lower Granite Dam tailrace generally decreased with later release date each year (Fig. 3). Estimated survival exceeded 50% for the first releases in early June 1998, and decreased to about 25% for the last releases in late June and early July (Table 6). Survival estimates were successively lower in each year, particularly for Pittsburg Landing release groups in 2000 and all release groups in the very low flows that occurred in 2001 (Table 6).

Survival estimates for weekly passage groups from Lower Granite Dam to Lower Monumental Dam tailrace were less precise than those for survival from release to Lower Granite Dam because sample sizes were typically much smaller (Table 7 and Fig. 4). In most years, average survival was fairly constant for groups leaving Lower Granite Dam until about 9 August, but was lower for fish that migrated later (Fig. 4). Annual average survival for groups until 9 August ranged from about 41% (1997) to 77% (1996), and averaged about 62% across all years. After 10 August, annual average survival ranged from 25% (1997) to 50% (1995), and averaged about 38% across all years. Estimated survival downstream of Lower Granite Dam was generally lower in 1997 and 2001 than in other years, especially in July and early August (Fig. 4). Late in 2001, release sizes at Lower Granite Dam were small (few fish were detected and returned to the river at Lower Granite Dam), and survival was apparently low, resulting in insufficient detections to estimate survival from mid-August through September.

Travel Time and Migration Rate

Pooling travel time data from all years of the study, median time from release in the Snake River until detection at Lower Granite Dam averaged 43.5 days (Table 8). The median travel time was nearly the same for fish released from Pittsburg Landing (173 km from Lower Granite Dam) as for those released at Billy Creek (92 km from Lower Granite Dam) (Table 8). The median elapsed time from release to the 5th percentile of Lower Granite Dam detections (median RTIME = 20.7 days) was almost the same as the average time between the 5th and 50th percentile detections (median MTIME = 22.8 days).

Within each migration year (pooled data from all groups each year), median migration rate between each pair of dams was substantially greater between Lower Monumental and McNary and between McNary and Bonneville Dams than between pairs of dams upstream from Lower Monumental Dam (Fig. 5 and Tables 8-12). Relative to the respective overall median, variability among annual median migration rates was generally greater in the upriver reaches. Similarly, relative to the annual median, variability among individual fish within a given reach (illustrated by range between 20^{th} and 80^{th} percentiles) was also greater in upriver reaches. The same patterns of variability could be seen in travel times (Fig. 5).

Comparison of Wild and Hatchery Subyearling Fall Chinook Salmon

Hatchery subyearling chinook salmon released at Pittsburg Landing and Billy Creek were generally shorter at release than wild counterparts in 1998 and 2000, especially for the later releases. Wild and hatchery fish were more similar in length in 1999 (hatchery fish in the two latest groups were longer than wild counterparts). In 2001, average length of hatchery fish ranged from 2 to 19 mm longer than that of wild fish (Table 13). Hatchery and wild fish both exhibited protracted travel times from release to Lower Granite Dam, with hatchery fish generally taking longer. Both groups passed Lower Granite Dam primarily in July and August. Wild fish passed earlier than hatchery fish in 1999. Estimated survival probabilities from release to Lower Granite Dam were similar for hatchery and wild subyearling chinook salmon during 1998 and 2001, but wild fish had considerably greater survival in 1999 and 2000.

PIT-Tag Detections During Spring After Overwintering

Fish released in 1999 were tagged with 400-kHz PIT tags and were not detected in the spring of 2000 because of the transition to 134.2-kHz tags and detectors. Overall, 1.5% of fish we released in 1998 were detected at Snake and Columbia River dams in spring 1999, and 1.0% of fish released in 2000 were detected in spring 2001 (Table 14).

Each spring, detections of fall chinook salmon released the previous summer as subyearlings began soon after the juvenile bypass systems began operation (late March or early April). Thus, detected fish were probably near a dam when bypass operation began, perhaps having migrated from rearing areas to the lower Snake River as subyearlings and having spent the winter in a reservoir. However, because detection systems were not operational during winter months, we lacked information to determine precisely where the fish spent the winter or when they resumed migration in the spring.

Among 1998 groups, groups released later in the year had slightly higher proportions detected in 1999 than earlier release groups (Table 14). Among groups released in 2000, the trend was just the opposite: slightly more fish released early in 2000 were detected in 2001 (Table 14). A greater proportion of fish released in the Clearwater River in 1998 were detected in 1999 than of those released in the Snake River (Table 14). For groups released in 1998, proportions detected in 1999 were similar between the two release sites in the Snake River. Of fish released in 2000, a higher proportion of those released at Billy Creek were detected in 2001 than of those released at Pittsburg Landing (Table 14). However, the difference between release sites in 2000 probably resulted from a difference in survival during 2000 (see Table 5) rather than a difference in propensity to overwinter.

In spring 1999 and 2001, PIT-tagged yearling fall chinook salmon reared at Lyons Ferry Hatchery were released from acclimation ponds at Pittsburg Landing and Captain John Rapids on the Snake River and at Big Canyon Creek on the Clearwater River. Total numbers released were 24,527 in 1999 and 17,520 in 2001. Of yearling fall chinook salmon that survived to

Lower Granite Dam in 1999, we estimated that about 79% were detected at least once and 95% of those that survived in 2001 were detected at least once. We assumed that for fish released as subyearlings that migrated out of the Snake River the following spring, detection probability was equal to that of yearlings released that spring. That is, the 331 fish (Table 14) released as subyearlings in 1998 and detected in 1999 represented 79% of the total that overwintered and migrated as yearlings in spring 1999, and the 146 fish released as subyearlings in 2000 and detected in 2001 represented 95% of the total for that year. Thus, we estimated that 1.9% (1.5%/0.79) of subyearlings released in 1998 and 1.1% (1.0%/0.95) of those released in 2000 actually migrated as yearlings the following spring.

Little is known about the overwinter survival probability of subyearling fall chinook salmon. Most subyearlings that suspend migration probably remain in reservoirs where they likely have low metabolic needs because water temperatures are low. Low temperatures also may inhibit predation rates. Assuming that overwinter survival was about 65% regardless of release date or site, we estimated that 2.9% (1.9%/0.65) of the subyearlings released in 1998 and 1.6% (1.1%/0.65) of those released in 2000 did not migrate in the year of release. Conversely, we estimated that the proportions of our PIT-tagged fish that migrated as subyearlings were 97.1% and 98.4% in 1998 and 2000, respectively.

River Conditions Associated with Survival and Travel Time, 1995-2001

Free-flowing Snake River to Lower Granite Dam

Results are based on groups released at Pittsburg Landing and Billy Creek on the free-flowing Snake River in 1995 (6 groups totaling 7,681 fish), 1996 (6 groups totaling 7,155 fish), and 1997 (12 groups totaling 14,952 fish)(Smith et al. 1997; Muir et al. 1998, 1999), and the 1998-2001 release groups at Pittsburg Landing and Billy Creek described above (Table 1). Groups released on 27 June 2001 were omitted from these analyses. While we were able to derive survival estimates using expanded daily detection probabilities, there were too few actual detections to estimate travel time and migration rate reliably. All told, between 1995 and 2001 there were 37 groups totaling 46,141 PIT-tagged subyearling fall chinook salmon released at Pittsburg Landing and 26 groups totaling 32,379 fish at Billy Creek

Experimental manipulation of flow, temperature, and turbidity was not attempted in this study. Instead, releases from storage reservoirs were managed to enhance migration conditions for smolts by increasing flow when Snake River flows became low or when water temperatures became high. Though there was annual variation, flow rate generally decreased throughout June and the first half of July, water temperature increased, and turbidity decreased, a pattern typical of natural runoff in the Snake River (Fig. 7). From mid-July until the end of summer, conditions were more constant. While flows in the Snake River Basin naturally reach minimum levels at this time of year, these flows were substantially elevated by releases from storage reservoirs and return flows from irrigation activities. A trend toward decreasing survival throughout the season accompanied the concomitant trends in environmental factors each year

(Figs. 3 and 7), but overall travel time and the length of rearing and migration periods did not show such obvious trends (Fig. 6).

Exposure indices were highly correlated with each other and with release date (Table 15). For example, the product-moment correlation coefficient (r) between date and rearing temperature exposure was 0.97; between rearing temperature and rearing flow the coefficient was -0.88 (all variables adjusted for annual means). Exposures in the rearing period were highly correlated with corresponding exposures in the migration period. The greatest such correlation $r = 0.92$) was between flow in the rearing period and flow in the migration period (Table 15).

Differences in annual means accounted for 41.4% of the overall variability of RTIME, and there were highly significant differences among annual means. RTIME was not associated with exposure indices or DATE (Fig. 8, left-hand column; Table 15).

It was difficult to summarize results for MTIME because patterns observed in 2001 were very different from those in other years (Fig. 8, middle column). Between 1995 and 2000, differences in annual means accounted for only 11.7% of the overall variability of MTIME, and annual means did not differ significantly. MTIME tended to increase later in the year, concomitant with decreasing flow, increasing temperature, and decreasing turbidity. In 2001, however, the ranges of MFLOW and MTURB were too narrow to discern any pattern, while MTIME decreased later in the year as the temperature increased, the opposite of the relations in the earlier years (Fig. 8, middle column).

We believe that the trend in observed MTIME in 2001 was probably not caused by increased migration speeds late in the season. It is more likely that longer travel times were not observed in 2001 because of high mortality rates: slower moving fish survived to Lower Granite Dam in such low numbers that the sample of observed travel times was heavily weighted toward the faster travelers. This effect probably operates to some degree in all years, but was especially pronounced in 2001. Detection numbers at Lower Granite Dam were moderately depressed for the first four weeks of the season in 2001. Beyond the fourth week, detections dropped off sharply in 2001 (Fig. 9). It appears that fish still above Lower Granite Dam around the beginning of July survived at a much lower rate than in past years; relatively few arrived at Lower Granite Dam to influence travel time estimates.

Because relations in data from 2001 appeared qualitatively different from all other years, the remaining results given for MTIME and TTIME are for 1995-2000 only. Because RTIME was relatively constant throughout migration seasons, patterns in TTIME (Fig. 8, right-hand column) were largely the same as those in MTIME. The strongest correlations for MTIME and TTIME were with the turbidity indices; longer travel times occurred in clearer water. In the most turbid water (Secchi disk reading less than 3 ft), MTIME was fairly constant. In clearer water, each 1-ft increase in Secchi disk reading was associated with an additional 14.8 days for the migration index period (Figure 8, right-hand column)($r^2 = 64.7\%$). MTIME and TTIME were fairly constant for groups released up until day 161 (10 June), and increased linearly thereafter. The increase in TTIME was 3.7 days for every 1 week difference in release date

(r^2 for this model: 56.5%) (Fig. 8, right-hand column). The relation between TTIME and MFLOW also had a threshold (64.3 kcfs) beyond which TTIME did not change appreciably. Below this threshold, the relation exhibited some curvature; decreases in TTIME became smaller as MFLOW levels neared the threshold (Fig. 8, right-hand column)(r^2 = 63.8%).

For estimated survival from release to Lower Granite Dam, differences in annual means accounted for 57.5% of the total variability. Product-moment correlations were generally much stronger for estimated survival than for the travel time variables (Table 16). Correlations with survival were generally stronger with rearing period indices than with migration period indices (Table 16). The strongest linear correlation was between estimated survival and release date (r^2 = 88.1% for the regression model with year effects and linear term for release date). However, this was partly because the relation between estimated survival and flow exposure was clearly not linear (Fig. 10).

Relations between RFLOW and SURV and between MFLOW and SURV were clearly nonlinear. Reasonable fits were achieved using year effects and a second-order polynomial for the flow index variable. Using the rearing period index, r^2 for this model was 89.8%. Using the migration period index, it was 84.0%. Because rearing periods for many early release groups included large periods of time before the end of natural spring runoff, and because migration periods were more likely to include the period when managed releases of water from storage reservoirs took place, the equation for the migration period index may be more useful for managers:

$$SURV = \text{Inter.} + 0.028717 * MFLOW - 0.0001397 * MFLOW^2$$

(intercepts = -0.499, -0.621, -0.815, -0.811, -0.892, -0.719, -0.582) for 1995-2001, respectively). A sigmoidal curve provided a useful alternative for relations between flow exposure and SURV (Fig. 10). For RFLOW the equation was

$$SURV = \frac{0.5940}{1 + e^{(72.16 - RFLOW)/13.26}} .$$

None of the three parameters were significantly different from year to year. The r^2 for this model was 82.9%, with only three parameters, six fewer than the polynomial regression with year effects.

For MFLOW, some parameters of the sigmoidal curve differed significantly among years. There appeared to be two separate “clusters” of years (Fig. 10). The first cluster was migration years 1995, 1996, 2000, and 2001. Boltzmann parameters for these four years did not differ significantly. Within each of the four years, only a narrow range in MFLOW values was observed, so that no single year contained a range that spanned the entire curve. Instead, the curve was effectively defined in segments with lowest MFLOW and SURV in 2000 an 2001, intermediate values in 1996, and greatest values in 1995. The equation for 1995, 1996, 2000, and 2001 was:

$$SURV = \frac{0.7278}{1 + e^{(43.39 - MFLOW)/4.946}} \ .$$

The three years 1997, 1998, and 1999 also shared parameters, with the equation:

$$SURV = \frac{0.6053}{1 + e^{(54.20 - MFLOW)/6.713}} \ .$$

Combining the two clusters, this model had six parameters and r^2 = 83.3%.

The relations between SURV and RTEMP and between SURV and MTEMP appeared linear for all years except 1997, in which there was notable curvature (Fig. 10). Additionally, year effects were highly significant in this model. The r^2 for this model was slightly lower than that for the polynomial model with the flow index: 89.0% for RTEMP and 78.8% for MTEMP. The equation for MTEMP in years other than 1997 was

$$SURV = \text{Inter.} - 0.0529 * MTEMP$$

(intercepts = 1.720, 1.369, 1.497, 1.280, 1.167, and 1.188 for 1995-2001 respectively). For 1997, a second-order polynomial described the data well:

$$SURV = -16.7512 + 2.0157 * MTEMP - 0.0583 * MTEMP^2.$$

Altogether, this model had 9 parameters and r^2 of 78.8%.

For turbidity, the range of RTURB was too narrow to discern a pattern in 2001. For years 1995 through 2000, the relation between SURV and RTURB appeared curved, with polynomial regression equation:

$$SURV = \text{Inter.} -0.4681 * RTURB + 0.0431 * RTURB^2$$

(intercepts = 1.690, 1.393, 1.233, 1.411, 1.084, 1.291 for 1995-2000, respectively; r^2 = 89.7%). The relation between SURV and MTURB in 2001 suitably fit a linear pattern established by 1995-2000 data (Fig. 10). For 1995 through 2001 data, the linear equation for MTURB showed a decrease in survival probability of 0.1727 for each 1-ft increase in Secchi disk reading (r^2 = 78.3%)(Fig. 10).

Between Lower Granite and Lower Monumental Dams

Results are based on 10 weekly groups detected and returned to the river at Lower Granite Dam in 1995 totaling 2,098 fish, 7 groups totaling 3,367 fish in 1996, and 14 groups totaling 15,461 fish in 1997 (Smith et al. 1997, Muir et al. 1998, 1999), and the 1998-2001 groups described above (Table 2). All told, between 1995 and 2001 there were 77 weekly groups totaling 58,833 PIT-tagged subyearling fall chinook salmon used in analyses of survival and travel time below Lower Granite Dam. Typically, the first weekly group for which survival was estimated passed Lower Granite Dam from 8 to 14 June (1 week later in 1995; 4 weeks later in 1996). The final weekly group passed between 7 and 13 September in three years, between 17 and 23 August in three years, and between 10 and 16 August in 2001.

Travel time and estimated survival between Lower Granite and Lower Monumental Dams were highly variable from year to year (Figs. 11 and 12). After adjusting for differences in annual means, considerable variation remained in relations among travel time, survival, and exposure indices, resulting in relatively low correlations (Table 17). Regression modeling resulted in few models with useful predictive power (Figs. 11 and 12). The relation between FLOW and SURV in 1997 was very different from the general pattern in other years (Fig. 12). The equation for 1997 (r^2 = 43.8%) was

$$SURV = 0.00855 + 0.006459*FLOW$$

and for 1995-2001, excluding 1997, the equation (r^2 = 32.7%) was

$$SURV = \frac{0.739}{1 + e^{(21.40 - FLOW)/10.14}}.$$

After adjusting for differences in yearly means, a linear relation between DATE and SURV was apparent (Fig. 12). In the regression model (r^2 = 53.9%), survival was constant within each year for groups that left before June 24 (Julian date 175), and the probability declined by 0.035 per week thereafter. The estimated “early-season” survival probabilities were 0.783, 0.834, 0.519, 0.774, 0.736, 0.697, and 0.552 for 1995-2001, respectively.

Survival Through McNary Dam Bypass System, 2000

A total of 51,922 juvenile salmonids were handled at McNary Dam during PIT tagging for bypass survival evaluation in 2000, 98.4% of which were subyearling chinook salmon, the target species (Table 18). Overall mortality from handling and tagging was 1.3%. Total flow ranged from a high of 231.5 kcfs to a low of 120.5 kcfs with spill levels ranging from 0 to 31.7% of total flow during the releases (Table 19). Water temperatures ranged from 16.1 to 20.0ºC.

With high levels of spill and poor guidance of subyearling chinook salmon, detection probabilities at John Day Dam were low for both gatewell and tailrace release groups (Tables 20 and 21), with corresponding imprecision in estimates of survival from release to John Day Dam tailrace (Tables 22 and 23). For this reason, the 14 daily release groups were combined to form 5 weekly groups. For weekly groups, estimated survival from release into the gatewell at McNary Dam to the tailrace of John Day Dam averaged 0.778 (s.e. 0.170). Estimated survival from release into the tailrace at McNary Dam to the tailrace of John Day Dam averaged 0.744 (s.e. 0.205). Estimated survival through the bypass system averaged (weighted geometric mean of ratios of estimated weekly survival) 1.007 (s.e. 0.388; Table 24).

Survival Between McNary and John Day Dams, 1998-2001

A total of 62,256 juvenile salmonids were handled at McNary Dam during PIT-tagging for survival evaluation in 2001, 95.3% of which were subyearling chinook salmon, the target species (Table 25). Overall mortality from handling and tagging was 1.9%. Total flow ranged from a high of 145.4 kcfs to a low of 66.9 kcfs, and there was no spill during the releases (Table 19). Water temperatures ranged from 16.7 to 21.8ºC. Estimated survival between McNary Dam and John Day Dam tailrace averaged 0.581 (s.e. 0.016) in 2001 (Table 26).

Among the four years from which survival estimates are available, 2001 had the lowest flow and least turbid water (Fig. 13). Water temperature in 2001 was higher than in 1999 and 2000, and slightly lower than in 1998. Among the three years during which we tagged and released fish in the tailrace of McNary Dam, travel times to John Day Dam were much longer in 2001 than in 1999 and 2000 (Fig. 14). For groups released on the same dates, median travel time to John Day Dam in 2001 ranged from 2 to 7.5 times as long as in 1999, and averaged about 4 times as long. Travel times in 2001 were also longer between John Day and Bonneville Dams, but to a much smaller degree (Fig. 14), averaging only about 1.5 as long as in 1999.

The lowest survival estimate (0.410, s.e. 0.115) was obtained in 1998, and the highest was in 1999 (0.775, s.e. 0.019) (Fig. 15). Estimates for 2000 and 2001 were intermediate (Tables 23 and 26). Correlations were not significant between average annual survival and the average river condition variables measured at McNary Dam (Fig. 16), but the correlation with temperature was considerably higher than for the other two variables. A more detailed investigation of survival from McNary Dam to John Day Dam and associated river conditions will appear in our annual report for 2002.

DISCUSSION

Assumptions

We assumed that the health and physiological status of fish from different groups throughout the six-week release schedule was sufficiently similar that patterns observed in survival and travel time were not artifacts of the rearing and release protocol. The decreasing trend in estimated survival from release to Lower Granite Dam is not likely an artifact of hatchery-rearing, as wild subyearling fall chinook salmon exhibit the same pattern (Connor et al. 2000, Connor 2001), and there is no discernible corresponding pattern in migrational timing. For example, if the physiological "readiness to migrate" of our release groups varied through time because of varying rearing times in the hatchery, we would expect to see evidence in travel time data as well as in survival data.

We assumed that hatchery subyearling fall chinook salmon would have post-release attributes and survival probabilities similar to their wild counterparts. Our rearing and release strategies were designed to produce hatchery subyearling chinook salmon with post-release attributes and survival probabilities similar to wild fish migrating from the free-flowing Snake River. Although hatchery fish were not perfect surrogates for wild fish, results of studies on wild subyearling fall chinook salmon in the Snake and Clearwater Rivers suggest this assumption was largely met. Hatchery fish spent an extended period of time rearing above Lower Granite Dam, migrated past Lower Granite Dam primarily during the summer months, and increased their rate of seaward movement as they progressed downstream as was observed during studies on wild subyearling fall chinook salmon (Connor et al. 2002, in press[a]). Additionally, survival probability estimates from release in the free-flowing Snake River to the tailrace of Lower Granite Dam decreased markedly from early to late release dates for both hatchery and wild subyearling fall chinook salmon (Connor et al. in press[b]). Though point estimates for hatchery fish were not always precise indices for wild counterparts, we believe that seasonal trends in estimated survival and travel time for wild fish were well represented by our weekly releases of hatchery-reared subyearling chinook salmon.

An assumption of the SR Model is that fish bypassed and detected at a dam and then returned to the river have the same subsequent survival as fish that survive dam passage but are not detected (spillway and turbine passage). Because detected and nondetected fish may occupy different portions of the tailrace before they remix as they move downstream, this violation could be violated if, for example, predator concentration is not uniform in the tailrace. Over the years of this study, most of our attempts to evaluate post-detection mortality at dams have been unsuccessful. In 1995, we held subyearling fall chinook salmon in raceways at Lower Granite Dam in anticipation of releasing paired groups during the period when fish from upstream releases were passing the dam. However, fish held in raceways grew at a much lower rate than those in the river, and were clearly not representative. From 1996 through 1998, we released large "secondary" groups of fish at Pittsburg Landing, planning to intercept them during migration to create paired release groups to estimate post-detection mortality. These efforts were unsuccessful because too few fish were intercepted at Lower Granite. In 1999 and 2000, we successfully estimated post-detection bypass mortality at McNary Dam using subyearling fall chinook salmon from the Hanford Reach. Results indicated that little or no mortality occurred. Therefore, we assumed post-detection bypass survival was 100%, and we used the SR Model to estimate survival for all primary release groups. If post-detection mortality occurred at all dams, then the SR Model would tend to overestimate survival from release to Lower Granite Dam. Survival estimates would also be biased for reaches below Lower Granite Dam, but the direction of the bias would depend on the relative degree of post-detection mortality at each dam.

The usual survival probability parameters of the statistical model must be interpreted as the joint probability of migrating during the period before dewatering of the PIT-tag interrogation system at the dam on the downstream end of the reach and the probability of surviving migration in that period. However, the small percentage of fish that did not migrate as subyearlings (less than 6% estimated annually for 1995-2000, and usually well below 6%) had minimal effect on subyearling survival estimates. To obtain a precise estimate of the proportion that overwinter would require operation of interrogation systems essentially year-round. However, the shape of the distribution of yearling detections in the spring following the year of release indicated that relatively few migrating fish passed while detection systems were dewatered. An exception might occur during winter flood events (such as the winter of 1995) under which conditions some winter passage has been documented (Connor et al. 1997, Connor 2001).

Detection and Survival Probabilities

In this report, we provide survival and travel time estimates from the free-flowing Snake River to Lower Granite Dam and from Lower Granite Dam downstream through the impounded Snake River for PIT-tagged subyearling fall chinook salmon. Substantial losses have been documented during rearing and migration to Lower Granite Dam each year, and relationships between release date, survival and environmental conditions have been identified. This information is useful to managers to help maximize survival to Lower Granite Dam. However, during the summer migration season, transportation is maximized for the untagged population of fall chinook salmon (both wild and hatchery subyearlings) so adult return rates for the population are largely dependent on survival after collection and transport to below Bonneville Dam. To date, information on smolt-to-adult return rates for barged or trucked fish is lacking since most PIT-tagged fish are returned to the Snake River by slide gates to continue their inriver migration. Information on return rates of transported PIT-tagged subyearling chinook salmon are needed to evaluate the efficacy of this mitigation strategy.

Survival and travel time from release to Lower Granite Dam was similar for groups released on the same date from Pittsburg Landing and from Billy Creek from 1995 through 1999. Similar travel times suggest that it did not take long for fish from Pittsburg Landing to travel the 82 km to Billy Creek, and thereafter fish from the two sites may have shared rearing habitat below Billy Creek, most likely in Lower Granite Reservoir. Survival estimates were substantially lower for Pittsburg Landing groups than for Billy Creek groups in 2000 and 2001. Movement from Pittsburg Landing may have been hindered by extremely low flow and lack of available cover (water was very clear and river-bank vegetation that offered refuge in other years was well above the waterline) may have led to increased predation. These results suggest that most of the mortality occurred in Lower Granite Reservoir except under the low flow conditions of 2000 and 2001 when mortality in the free-flowing river was apparent.

River flow, water temperature, and turbidity may affect survival of hatchery subyearling fall chinook salmon in a number of ways. Survival could be decreased because delays in passage may occur under lower flow experienced by hatchery fish released late in the season, compared to those released early in the season. Hypothesized consequences of such delays are disorientation of migrants, increased exposure time to predators, higher rates of overwintering, and increased susceptibility to disease (Park 1969, Raymond 1988, Berggren and Filardo 1993). Warmer water during later releases of hatchery subyearling fall chinook salmon increases metabolic costs of rearing and migration (Groot et al. 1995). In addition, warmer water could result in increased predation rates due to increased metabolic needs of predators (Vigg and Burley 1991, Vigg et al. 1991, Curet 1993). Clearer water (lower turbidity) could increase vulnerability to sight-feeding predators (Hobson 1979, Zaret 1979) by increasing predator reactive distance and predator encounter rates (Vinyard and O'Brien 1976, Shively et al. 1991). Greater turbidity could reduce predation rates on juvenile salmonids by providing protective cover during rearing (Simenstad et al. 1982, Gregory 1993, Gregory and Levings 1998).

Predator abundance and feeding activity, in concert with decreased flow and increased water temperature, may have caused the steady decline in survival probability estimates from early to late release dates. Isaak and Bjornn (1996) found that the peak abundance of northern squawfish *Ptychocheilus oregonensis* in the tailrace of Lower Granite Dam occurred in July, during the subyearling fall chinook salmon migration. Poe et al. (1991), Shively et al. (1996) and Zimmerman (1999) found that predation rates depended on the size of juvenile salmonids, with smaller fish more vulnerable to predation. Fish size is known to affect migration rates in fall chinook salmon, with smaller fish rearing longer in upstream areas before initiating migration (Connor et al. 2000). Thus, small hatchery subyearling fall chinook salmon released late in the year may experience higher predation rates. A similar fate is expected for wild fall chinook salmon that emerge later, which could account for the low survival probability estimates to the tailrace of Lower Granite Dam reported for fish from the Clearwater River (Connor et al. 1997, Connor 2001).

High interannual variability in travel time and survival between Lower Granite and Lower Monumental Dams appears to have as much to do with conditions upstream of Lower Granite Dam as with conditions in the reservoirs. For example, median travel time decreased with increased discharge in most years. However, in 1997 the longest travel times in this reach occurred at the highest discharge. Also, survival relations in 1997 did not fit the general pattern for other years. We believe that fish we released above Lower Granite Dam in early June 1997 were affected by higher than average discharge levels throughout June and July. Instead of rearing above Lower Granite Dam, as is typical in lower-water years, the earliest fish were probably "flushed out" prematurely, and completed their rearing in reservoirs below Lower Granite Dam. Among fish sampled as they passed Little Goose Dam, average size was substantially smaller (30 to 40 mm shorter) than in other years (Smith et al. 1997; Muir et al. 1998; Muir et al. 1999). Their smaller size in 1997 would increase their vulnerability to predators in this reach.

Lack of predictive ability for survival and travel time downstream of Lower Granite Dam may be due to the fact that estimates typically have more variability because sample sizes are much smaller than for estimates above Lower Granite Dam, and ranges of environmental exposures for the groups tend to be restricted because subyearling fall chinook salmon migrate through this reach during summer when conditions are relatively constant.

Travel Time and Migration Rate

The apparent threshold levels observed in many of the relations for travel time upstream of Lower Granite Dam suggested that early in the season, when flow is high and water is relatively cool and turbid, travel times are not much affected by increases in flow. However, later in the season the opportunity becomes greater to influence travel time by releasing water from storage reservoirs. Curvature in some of the relations suggested that the greatest potential effect on travel times occurs when flow is lowest and water is warmest and clearest.

Relating travel time of actively migrating subyearling fall chinook salmon to environmental variables through reservoir reaches has proved difficult for researchers and has produced conflicting results. Giorgi et al. (1997) found that PIT-tagged subyearling chinook salmon in the mid-Columbia River showed no response to flow or temperature, although there was a significant positive correlation between fish length and migration rate; whereas Berggren and Filardo (1993) found faster migration with higher flow and lower water temperature. Results are likely affected by the time and location of tagging and release of subyearling fall chinook salmon, as they rear and develop physiologically during the migration period and their migration rate generally increases with migration distance and increased size.

Prospects for Manipulative Experiments

In each year of the study, decreasing survival from release to the tailrace of Lower Granite Dam was accompanied by decreasing river flow, increasing water temperature, and decreasing turbidity. These trends resulted in strong and highly significant correlations, not only between survival estimates and river conditions, but among the conditions themselves. High collinearity among the three environmental predictor variables precluded determination of which variable most strongly influenced survival.

Sorting out the effects of individual environmental factors (i.e., temperature, flow, turbidity) on survival will require manipulative studies. We did not manipulate environmental factors during our study. Because of efforts to increase the survival of ESA listed juvenile Snake River fall chinook salmon, and because of other limitations affecting federal and privately owned water storage projects, manipulating these factors to create a more rigorous factorial experimental design will be difficult. Experimental manipulation would likely be restricted to withdrawal of water from upstream storage reservoirs; experimenters could have little effect on water turbidity and temperature without also affecting discharge. The temperature of water withdrawn differs between the two main storage reservoirs above Lower Granite Dam, Dworshak and Brownlee (Connor et al. 1998), so there is some opportunity to create conditions of equal discharge with varying water temperature. However, creating simultaneous conditions of high temperatures and high discharge levels is nearly impossible.

As are designers of experiments, fishery managers are limited in their options for increasing survival of subyearling chinook salmon by affecting river conditions. However, withdrawal of cool water from upstream storage reservoirs in the summer ("summer flow augmentation") appears to be an efficacious option, even if effects on survival of various factors cannot be distinguished statistically. Provided the water released upstream is not too warm, flow augmentation is likely to influence all three variables in the direction related to higher survival. For wild Snake River juvenile fall chinook salmon, Connor et al. (1998) found that proportions detected at Lower Granite Dam were significantly correlated with both average seasonal flow and average seasonal water temperature, similar to our results using hatchery subyearling fall chinook salmon. Connor et al. concluded that their results supported flow augmentation that provides both increased flow and reduced water temperature as a beneficial interim recovery measure for enhancing survival of subyearling chinook salmon in the Snake River. The results of our study would support that recommendation.

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Table 1. Information for groups of PIT-tagged hatchery subyearling fall chinook salmon released from 1998 to 2001. Water temperatures were measured at release sites. Mortality is total for tagging and transportation.

Release site	Release date	Number released	Water temp. (°C)	Mean length (mm)	Mortality N	Mortality %
			1998			
Pittsburg Landing	2 Jun	1,277	16.4	72.5	80	6.3
	9 Jun	1,274	16.0	72.2	8	0.6
	16 Jun	1,251	16.8	74.9	7	0.6
	23 Jun	1,279	18.3	74.7	18	1.4
	30 Jun	1,273	18.9	74.9	12	0.9
Billy Creek	2 Jun	1,262	13.9	73.2	15	1.2
	9 Jun	1,273	13.7	72.8	3	0.2
	16 Jun	1,261	14.5	76.3	6	0.5
	23 Jun	1,259	16.2	73.0	24	1.9
	30 Jun	1,249	17.5	75.7	2	0.2
	7 Jul	1,266	19.5	78.2	5	0.4
Big Canyon Creek	2 Jun	1,254	12.4	71.8	49	3.9
	9 Jun	1,274	13.7	73.7	10	0.8
	16 Jun	1,271	14.6	75.2	16	1.3
	23 Jun	1,264	14.8	77.8	4	0.3
	30 Jun	1,254	16.1	78.0	10	0.8
	7 Jul	1,288	18.7	76.4	7	0.5
			1999			
Pittsburg Landing	1 Jun	1,239	14.8	79.0	10	0.8
	8 Jun	1,249	16.0	79.9	2	0.2
	15 Jun	1,249	17.3	79.6	5	0.4
	22 Jun	1,256	18.8	80.7	1	0.1
	29 Jun	1,238	19.2	83.5	12	1.0
	6 Jul	1,249	19.3	93.0	2	0.2
Asotin	1 Jun	1,225	12.9	76.1	22	1.8
	8 Jun	1,235	11.9	77.6	17	1.4
	15 Jun	1,236	15.0	78.9	14	1.1
	22 Jun	1,251	15.0	79.7	4	0.3
	29 Jun	1,241	15.9	82.2	9	0.7
	6 Jul	1,249	17.5	95.8	0	0.0
Big Canyon Creek	1 Jun	1,228	9.6	77.7	16	1.3
	8 Jun	1,247	9.0	78.3	12	1.0
	15 Jun	1,240	12.4	79.0	13	1.0
	22 Jun	1,251	11.5	79.8	7	0.6
	29 Jun	1,255	13.5	87.7	2	0.2
	6 Jul	1,244	14.9	90.9	0	0.0

Table 1. Continued.

Release site	Release date	Number released	Water temp. (ºC)	Mean length (mm)	Mortality N	Mortality %
2000						
Pittsburg Landing	1 Jun	1,241	16.7	82.1	1	0.1
	8 Jun	1,225	17.0	82.8	21	1.7
	15 Jun	1,249	17.0	82.9	7	0.6
	22 Jun	1,238	18.0	83.1	6	0.5
	29 Jun	1,230	20.0	85.7	13	1.0
	6 Jul	1,244	19.0	86.7	5	0.4
Billy Creek	1 Jun	1,239	13.1	80.3	7	0.6
	8 Jun	1,234	15.9	80.5	17	1.4
	15 Jun	1,243	16.2	81.6	8	0.6
	22 Jun	1,236	18.4	82.9	12	1.0
	29 Jun	1,246	20.6	85.1	3	0.2
	6 Jul	1,241	19.5	84.8	8	0.6
2001						
Pittsburg Landing	23 May	1,246	14.6	88.0	0	0.0
	30 May	1,244	14.9	88.6	0	0.0
	6 Jun	1,247	15.3	90.7	0	0.0
	13 Jun	1,247	14.5	89.8	0	0.0
	20 Jun	1,243	16.1	92.4	0	0.0
	27 Jun	1,250	16.4	94.4	0	0.0
Billy Creek	23 May	1,248	14.3	87.0	1	0.1
	30 May	1,248	13.2	87.8	1	0.1
	6 Jun	1,246	12.5	90.6	3	0.2
	13 Jun	1,248	13.5	86.5	0	0.0
	20 Jun	1,245	16.0	91.7	0	0.0
	27 Jun	1,250	17.0	92.1	1	0.1

Table 2. Numbers of PIT-tagged subyearling fall chinook salmon passing Lower Granite Dam each week, 1998-2001. Includes wild fish and fish reared at Lyons Ferry Hatchery. Bold type indicates weeks for which survival estimates were possible; data were not sufficient in other weeks.

Lower Granite Dam passage dates	1998	1999	2000	2001
18-24 May	30	0	0	6
25-31 May	116	0	0	62
1-7 Jun	63	43	25	979
8-14 Jun	**60**	**229**	**68**	**3,047**
15-21 Jun	**93**	**436**	**150**	**318**
22-28 Jun	**355**	**407**	**337**	**559**
29 Jun-5 Jul	**510**	**197**	**1,059**	**2,298**
6-12 Jul	**5,292**	**133**	**487**	**1,638**
13-19 Jul	**6,073**	**691**	**232**	**593**
20-26 Jul	**2,334**	**1,131**	**81**	166
27 Jul-2 Aug	**1,422**	**811**	**105**	**148**
3-9 Aug	**1,304**	**835**	**166**	**166**
10-16 Aug	**1,166**	**576**	**91**	**866**
17-23 Aug	**370**	**322**	49	159
24-30 Aug	**213**	265	**103**	94
31 Aug.-6 Sep	60	47	**95**	50
7-13 Sep	**224**	0	**116**	25
14-20 Sep	102	0	51	57
21-27 Sep	231	0	44	101
28 Sep.-5 Oct	157	0	31	26
6-12 Oct	97	0	34	2
13-19 Oct	35	0	13	20
20-26 Oct	16	0	60	3
27 Oct.-2 Nov	7	0	54	66
Total	20,330	6,123	3,451	11,449
Total used for survival estimation	19,416	5,768	3,090	10,612

Table 3. Tests of homogeneity for detection distributions at Little Goose, Lower Monumental, and McNary Dams for subgroups of groups released from Pittsburg Landing (PL), Big Canyon Creek (CW), Billy Creek (BC), and Asotin (AS), 1998-2001. Subgroups were defined by detection histories at previous dams. P values calculated using Monte Carlo approximation of the exact method. Shaded cells indicate P values less than 0.10.

	Little Goose Dam			Lower Monumental Dam			McNary Dam		
Release	χ^2	d.f.	P value	χ^2	d.f.	P value	χ^2	d.f.	P value
				1998					
PL 1	63.4	41	0.002	143.0	111	0.006	256.9	252	0.423
PL 2	59.7	39	0.006	110.0	117	0.748	255.8	259	0.572
PL 3	61.4	50	0.068	132.4	138	0.619	305.7	308	0.573
PL 4	45.1	41	0.261	101.2	96	0.305	210.5	210	0.580
PL 5	31.3	32	0.601	80.5	78	0.430	183.6	182	0.648
CW 1	57.9	40	0.006	112.1	96	0.077	298.0	280	0.193
CW 2	50.9	44	0.180	104.7	123	0.948	281.7	280	0.494
CW 3	56.3	48	0.138	137.8	144	0.724	297.1	301	0.600
CW 4	67.9	59	0.119	122.0	123	0.563	239.7	266	0.970
CW 5	55.4	53	0.357	108.6	102	0.231	263.2	259	0.474
CW 6	49.9	37	0.012	117.0	102	0.025	187.7	175	0.214
BC 1	68.0	36	<0.001	101.4	102	0.514	266.3	259	0.347
BC 2	38.6	40	0.576	117.4	117	0.489	251.8	231	0.138
BC 3	59.1	49	0.093	151.1	141	0.215	270.4	245	0.082
BC 4	50.6	50	0.468	136.5	135	0.489	300.0	280	0.151
BC 5	43.8	44	0.531	90.3	93	0.684	141.2	156	0.974
BC 6	35.9	39	0.772	92.8	84	0.136	159.8	161	0.710

Table 3. Continued.

Release	Little Goose Dam χ^2	d.f.	P value	Lower Monumental Dam χ^2	d.f.	P value	McNary Dam χ^2	d.f.	P value
1999									
PL 1	61.2	63	0.573	156.1	147	0.256	220.9	217	0.523
PL 2	74.9	55	0.006	148.4	141	0.271	263.0	238	0.162
PL 3	41.8	40	0.390	74.3	75	0.637	118.6	126	0.803
PL 4	28.8	37	0.953	94.0	84	0.153	161.8	161	0.610
PL 5	16.0	15	0.677	29.6	27	0.517	60.5	54	0.541
PL 6	4.5	5	1.0	NA	NA	NA	NA	NA	NA
CW 1	65.1	60	0.255	143.0	120	0.032	244.7	224	0.187
CW 2	47.4	46	0.439	119.1	114	0.330	124.7	126	0.713
CW 3	41.8	35	0.124	88.6	93	0.762	166.4	147	0.097
CW 4	21.4	26	0.880	56.4	57	0.641	148.0	140	0.376
CW 5	10.6	11	1.0	8.0	4	0.156	8	6	1
CW 6	NA	NA	NA	NA	NA	NA	NA	NA	NA
AS 1	61.3	59	0.408	137.7	132	0.341	189.4	182	0.413
AS 2	62.5	57	0.215	142.6	141	0.483	238.5	231	0.401
AS 3	49.8	40	0.065	94.7	96	0.631	134.2	138	0.783
AS 4	30.0	27	0.277	55.4	54	0.509	71.6	70	0.599
AS 5	21.5	18	0.241	24.9	27	0.928	70.0	66	0.616
AS 6	11.0	9	0.566	8	6	1	3	2	1

Table 3. Continued.

Release	Little Goose Dam χ^2	d.f.	P value	Lower Monumental Dam χ^2	d.f.	P value	McNary Dam χ^2	d.f.	P value
2000									
PL 1	41.3	35	0.156	79.5	78	0.491	194.0	182	0.299
PL 2	14.0	14	1	14.0	12	1	21	15	0.137
PL 3	33.0	31	0.342	50.5	48	0.607	40	36	1
PL 4	7	6	1	NA	NA	NA	12	10	1
PL 5	8	7	1	5	4	1	10	8	1
PL 6	6	5	1	16	14	1	NA	NA	NA
BC 1	80.3	59	0.007	170.7	168	0.442	309.5	301	0.376
BC 2	44.5	45	0.539	90.8	87	0.363	179.1	161	0.204
BC 3	43.0	42	0.470	67.0	66	0.692	131.9	132	0.963
BC 4	36.6	32	0.149	54.2	54	0.758	87.5	84	0.934
BC 5	21.9	19	0.182	26.0	24	1	21	18	1
BC 6	7	6	1	14	12	0.794	3	2	1
2001									
PL 1	23.7	32	0.987	52.8	48	0.243	6.7	6	0.899
PL 2	19.2	12	0.014	14	12	1	NA	NA	NA
PL 3	8.5	9	0.999	6	4	1	NA	NA	NA
PL 4	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL 5	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL 6	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC 1	43.2	49	0.786	129.5	120	0.188	180.0	196	0.954
BC 2	100.4	90	0.128	100.4	90	0.132	100.1	108	0.850
BC 3	31.9	28	0.160	41.9	39	0.698	20	16	1
BC 4	14.9	16	0.929	4	3	1	NA	NA	NA
BC 5	5	4	1	NA	NA	NA	NA	NA	NA
BC 6	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4. Results of tests of goodness of fit to the Single-Release Model for release groups from Pittsburg Landing (PL), Big Canyon Creek (CW), Billy Creek (BC), and Asotin (AS), 1998-2001. Shaded cells indicate P values less than 0.10.

	Overall		Test 2		Test 2.C2		Test 2.C3		Test 3		Test 3.SR3		Test 3.Sm3		Test 3.SR4	
Release	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value	χ^2	P value
1998																
PL 1	11.649	0.070	3.528	0.317	2.551	0.279	0.977	0.323	8.121	0.044	5.151	0.023	2.367	0.124	0.603	0.437
PL 2	11.259	0.081	2.396	0.494	1.448	0.485	0.948	0.330	8.863	0.031	6.178	0.013	1.44	0.230	1.245	0.265
PL 3	2.081	0.912	0.430	0.934	0.400	0.819	0.030	0.862	1.651	0.648	0.512	0.474	0	1.000	1.139	0.286
PL 4	4.500	0.609	4.249	0.236	3.974	0.137	0.275	0.600	0.251	0.969	0.115	0.735	0.044	0.834	0.092	0.762
PL 5	4.078	0.666	2.950	0.399	2.136	0.344	0.814	0.367	1.128	0.770	0.730	0.393	0.38	0.538	0.018	0.893
CW 1	11.742	0.068	6.739	0.081	4.067	0.131	2.672	0.102	5.003	0.172	2.187	0.139	0.244	0.621	2.572	0.109
CW 2	18.255	0.006	3.279	0.351	3.254	0.197	0.025	0.874	14.976	0.002	1.033	0.309	10.575	0.001	3.368	0.066
CW 3	15.078	0.020	1.757	0.624	1.682	0.431	0.075	0.784	13.321	0.004	8.619	0.003	0.293	0.588	4.409	0.036
CW 4	4.773	0.573	1.900	0.593	1.899	0.387	0.001	0.975	2.873	0.412	0.547	0.460	0.003	0.956	2.323	0.127
CW 5	16.544	0.011	6.755	0.080	4.353	0.113	2.402	0.121	9.789	0.020	3.542	0.060	0.893	0.345	5.354	0.021
CW 6	0.695	0.995	0.238	0.971	0.150	0.928	0.088	0.767	0.457	0.928	0.233	0.629	0.189	0.664	0.035	0.852
BC 1	5.479	0.484	1.516	0.679	1.002	0.606	0.514	0.473	3.963	0.265	2.687	0.101	0.253	0.615	1.023	0.312
BC 2	2.388	0.881	1.852	0.604	1.831	0.400	0.021	0.885	0.536	0.911	0.126	0.723	0.02	0.888	0.39	0.532
BC 3	5.904	0.434	4.241	0.237	0.981	0.612	3.260	0.071	1.663	0.645	0.164	0.686	1.244	0.265	0.255	0.614
BC 4	11.691	0.069	2.878	0.411	2.611	0.271	0.267	0.605	8.813	0.032	7.870	0.005	0.9	0.343	0.043	0.836
BC 5	15.006	0.020	14.949	0.002	13.745	0.001	1.204	0.273	0.057	0.996	0.056	0.813	0.001	0.975	0	1.000
BC 6	8.225	0.222	5.283	0.152	4.251	0.119	1.032	0.310	2.942	0.401	1.195	0.274	1.351	0.245	0.396	0.529

Table 4. Continued.

Release	Overall χ²	Overall P value	Test 2 χ²	Test 2 P value	Test 2.C2 χ²	Test 2.C2 P value	Test 2.C3 χ²	Test 2.C3 P value	Test 3 χ²	Test 3 P value	Test 3.SR3 χ²	Test 3.SR3 P value	Test 3.Sm3 χ²	Test 3.Sm3 P value	Test 3.SR4 χ²	Test 3.SR4 P value
1999																
PL 1	1.920	0.927	1.096	0.778	0.095	0.954	1.001	0.317	0.824	0.844	0.545	0.460	0.272	0.602	0.007	0.933
PL 2	7.558	0.272	1.840	0.606	0.769	0.681	1.071	0.301	5.718	0.126	1.150	0.284	3.334	0.068	1.234	0.267
PL 3	13.028	0.043	3.239	0.356	2.734	0.255	0.505	0.477	9.789	0.020	2.957	0.086	6.806	0.009	0.026	0.872
PL 4	7.868	0.248	4.207	0.240	4.136	0.126	0.071	0.790	3.661	0.300	2.887	0.089	0.423	0.515	0.351	0.554
PL 5	2.572	0.860	1.604	0.658	1.604	0.448	NA	NA	0.968	0.809	0.002	0.964	0.225	0.635	0.741	0.389
PL 6	0.467	0.494	NA	NA	NA	NA	NA	NA	0.467	0.494	0.467	0.494	NA	NA	NA	NA
CW 1	5.981	0.425	2.517	0.472	2.326	0.313	0.191	0.662	3.464	0.325	0.848	0.357	1.993	0.158	0.623	0.430
CW 2	3.621	0.728	2.483	0.478	2.279	0.320	0.204	0.652	1.138	0.768	0.175	0.676	0.013	0.909	0.95	0.330
CW 3	7.910	0.245	6.013	0.111	6.012	0.049	0.001	0.975	1.897	0.594	0.330	0.566	1.524	0.217	0.043	0.836
CW 4	6.373	0.383	2.051	0.562	0.644	0.725	1.407	0.236	4.322	0.229	1.115	0.291	2.885	0.089	0.322	0.570
CW 5	3.315	0.652	1.075	0.783	0.450	0.799	0.625	0.429	2.240	0.326	1.040	0.308	1.2	0.273	NA	NA
CW 6	2.000	0.157	2.000	0.157	NA	NA	2.000	0.157	NA	NA	NA	NA	NA	NA	NA	NA
AS 1	1.335	0.970	0.643	0.887	0.436	0.804	0.207	0.649	0.692	0.875	0.056	0.813	0.478	0.489	0.158	0.691
AS 2	3.823	0.701	2.180	0.536	2.117	0.347	0.063	0.802	1.643	0.650	0.324	0.569	0.991	0.319	0.328	0.567
AS 3	8.462	0.206	1.355	0.716	1.210	0.546	0.145	0.703	7.107	0.069	0.842	0.359	0.207	0.649	6.058	0.014
AS 4	5.926	0.432	4.262	0.235	0.414	0.813	3.848	0.050	1.664	0.645	0.373	0.541	0.042	0.838	1.249	0.264
AS 5	5.131	0.527	1.004	0.800	0.998	0.607	0.006	0.938	4.127	0.248	2.851	0.091	0.225	0.635	1.051	0.305
AS 6	5.450	0.244	4.379	0.223	3.846	0.146	0.533	0.465	1.071	0.301	1.071	0.301	NA	NA	NA	NA

Table 4. Continued.

Release	Overall χ^2	Overall P value	Test 2 χ^2	Test 2 P value	Test 2.C2 χ^2	Test 2.C2 P value	Test 2.C3 χ^2	Test 2.C3 P value	Test 3 χ^2	Test 3 P value	Test 3.SR3 χ^2	Test 3.SR3 P value	Test 3.Sm3 χ^2	Test 3.Sm3 P value	Test 3.SR4 χ^2	Test 3.SR4 P value
2000																
PL 1	15.735	0.015	14.911	0.002	14.452	0.001	0.459	0.498	0.824	0.844	0.545	0.460	0.272	0.602	0.007	0.933
PL 2	10.984	0.089	5.266	0.153	5.214	0.074	0.052	0.820	5.718	0.126	1.150	0.284	3.334	0.068	1.234	0.267
PL 3	11.972	0.063	2.183	0.535	2.124	0.346	0.059	0.808	9.789	0.020	2.957	0.086	6.806	0.009	0.026	0.872
PL 4	3.661	0.300	NA	NA	NA	NA	NA	NA	3.661	0.300	2.887	0.089	0.423	0.515	0.351	0.554
PL 5	4.058	0.669	3.090	0.378	3.000	0.223	0.090	0.764	0.968	0.809	0.002	0.964	0.225	0.635	0.741	0.389
PL 6	0.467	0.494	NA	NA	NA	NA	NA	NA	0.467	0.494	0.467	0.494	NA	NA	NA	NA
BC 1	8.708	0.191	8.016	0.046	2.898	0.235	5.118	0.024	0.692	0.875	0.056	0.813	0.478	0.489	0.158	0.691
BC 2	4.870	0.561	3.227	0.358	2.577	0.276	0.650	0.420	1.643	0.650	0.324	0.569	0.991	0.319	0.328	0.567
BC 3	9.271	0.159	2.164	0.539	1.788	0.409	0.376	0.540	7.107	0.069	0.842	0.359	0.207	0.649	6.058	0.014
BC 4	4.332	0.632	2.668	0.446	2.478	0.290	0.190	0.663	1.664	0.645	0.373	0.541	0.042	0.838	1.249	0.264
BC 5	11.451	0.075	7.324	0.062	3.375	0.185	3.949	0.047	4.127	0.248	2.851	0.091	0.225	0.635	1.051	0.305
BC 6	4.992	0.288	3.921	0.270	0.321	0.852	3.600	0.058	1.071	0.301	1.071	0.301	NA	NA	NA	NA
2001																
PL 1	1.178	0.978	0.366	0.947	0.361	0.835	0.005	0.944	0.812	0.847	0.587	0.444	0.101	0.751	0.124	0.725
PL 2	6.398	0.269	0.993	0.803	0.672	0.715	0.321	0.571	5.405	0.067	2.405	0.121	NA	NA	3.000	0.083
PL 3	6.521	0.163	5.115	0.164	3.782	0.151	1.333	0.248	1.406	0.236	1.406	0.236	NA	NA	NA	NA
PL 4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL 5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL 6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC 1	4.557	0.602	0.636	0.888	0.210	0.900	0.426	0.514	3.921	0.270	1.661	0.197	0.900	0.343	1.360	0.244
BC 2	4.526	0.606	1.040	0.792	0.894	0.640	0.146	0.702	3.486	0.323	0.735	0.391	2.732	0.098	0.019	0.890
BC 3	8.872	0.181	4.245	0.236	1.996	0.369	2.249	0.134	4.627	0.201	4.435	0.035	0.178	0.673	0.014	0.906
BC 4	5.519	0.238	2.356	0.308	1.523	0.217	0.833	0.361	3.163	0.206	0.163	0.686	3.000	0.083	NA	NA
BC 5	2.880	0.090	2.880	0.090	2.880	0.090	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC 6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 5. Estimated detection probabilities for subyearling fall chinook salmon PIT tagged at Lyons Ferry Hatchery and released in free-flowing sections of the Snake and Clearwater Rivers, 1998-2001. Estimates based on the Single-Release Model. Standard errors in parentheses.

Release site	Date	Number released	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam	
1998								
Pittsburg Landing	2 Jun	1,277	0.465	(0.024)	0.658	(0.027)	0.479	(0.036)
Billy Creek	2 Jun	1,262	0.538	(0.023)	0.628	(0.026)	0.443	(0.035)
Big Canyon Creek	2 Jun	1,254	0.468	(0.025)	0.621	(0.029)	0.428	(0.037)
Pittsburg Landing	9 Jun	1,274	0.521	(0.024)	0.618	(0.028)	0.394	(0.036)
Billy Creek	9 Jun	1,273	0.485	(0.025)	0.660	(0.028)	0.376	(0.036)
Big Canyon Creek	9 Jun	1,274	0.510	(0.023)	0.585	(0.028)	0.439	(0.036)
Pittsburg Landing	16 Jun	1,251	0.509	(0.026)	0.597	(0.030)	0.392	(0.036)
Billy Creek	16 Jun	1,261	0.477	(0.026)	0.600	(0.031)	0.470	(0.041)
Big Canyon Creek	16 Jun	1,271	0.496	(0.026)	0.616	(0.030)	0.417	(0.039)
Pittsburg Landing	23 Jun	1,279	0.407	(0.039)	0.570	(0.049)	0.404	(0.063)
Billy Creek	23 Jun	1,259	0.473	(0.034)	0.610	(0.040)	0.407	(0.051)
Big Canyon Creek	23 Jun	1,264	0.512	(0.029)	0.595	(0.035)	0.424	(0.045)
Pittsburg Landing	30 Jun	1,273	0.466	(0.051)	0.558	(0.060)	0.395	(0.075)
Billy Creek	30 Jun	1,249	0.447	(0.041)	0.502	(0.051)	0.311	(0.066)
Big Canyon Creek	30 Jun	1,254	0.419	(0.035)	0.571	(0.043)	0.421	(0.056)
Billy Creek	7 Jul	1,266	0.440	(0.044)	0.533	(0.055)	0.438	(0.072)
Big Canyon Creek	7 Jul	1,288	0.410	(0.045)	0.603	(0.056)	0.422	(0.074)

Table 5. Continued.

Release site	Date	Number released	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam	
					1999			
Pittsburg Landing	1 Jun	1,239	0.370	(0.029)	0.506	(0.038)	0.477	(0.058)
Asotin	1 Jun	1,225	0.411	(0.034)	0.682	(0.043)	0.483	(0.068)
Big Canyon Creek	1 Jun	1,228	0.391	(0.034)	0.564	(0.044)	0.362	(0.065)
Pittsburg Landing	8 Jun	1,249	0.480	(0.031)	0.575	(0.040)	0.309	(0.054)
Asotin	8 Jun	1,235	0.439	(0.033)	0.628	(0.039)	0.300	(0.050)
Big Canyon Creek	8 Jun	1,247	0.416	(0.040)	0.576	(0.050)	0.359	(0.073)
Pittsburg Landing	15 Jun	1,249	0.589	(0.044)	0.526	(0.059)	0.188	(0.063)
Asotin	15 Jun	1,236	0.531	(0.043)	0.655	(0.052)	0.413	(0.072)
Big Canyon Creek	15 Jun	1,240	0.526	(0.045)	0.644	(0.054)	0.347	(0.074)
Pittsburg Landing	22 Jun	1,256	0.610	(0.042)	0.572	(0.053)	0.471	(0.078)
Asotin	22 Jun	1,251	0.638	(0.052)	0.524	(0.070)	0.255	(0.082)
Big Canyon Creek	22 Jun	1,251	0.597	(0.052)	0.509	(0.066)	0.415	(0.078)
Pittsburg Landing	29 Jun	1,238	0.640	(0.088)	0.500	(0.118)	0.545	(0.140)
Asotin	29 Jun	1,241	0.620	(0.071)	0.407	(0.103)	0.286	(0.121)
Big Canyon Creek	29 Jun	1,255	0.713	(0.109)	0.600	(0.155)	NA	NA
Pittsburg Landing	6 Jul	1,249	0.286	(0.171)	NA	NA	NA	NA
Asotin	6 Jul	1,249	0.642	(0.118)	0.398	(0.173)	NA	NA
Big Canyon Creek	6 Jul	1,244	0.529	(0.351)	0.500	(0.354)	NA	NA

Table 5. Continued.

Release site	Date	Number released	Lower Granite Dam		Little Goose Dam		Lower Monumental Dam	
2000								
Pittsburg Landing	1 Jun	1,241	0.653	(0.042)	0.640	(0.053)	0.415	(0.072)
Billy Creek	1 Jun	1,239	0.661	(0.029)	0.643	(0.040)	0.463	(0.056)
Pittsburg Landing	8 Jun	1,225	0.536	(0.106)	0.578	(0.146)	0.467	(0.186)
Billy Creek	8 Jun	1,234	0.722	(0.038)	0.554	(0.062)	0.306	(0.084)
Pittsburg Landing	15 Jun	1,249	0.550	(0.068)	0.648	(0.095)	0.414	(0.156)
Billy Creek	15 Jun	1,243	0.641	(0.048)	0.550	(0.073)	0.288	(0.091)
Pittsburg Landing	22 Jun	1,238	0.576	(0.156)	0.700	(0.179)	NA	NA
Billy Creek	22 Jun	1,236	0.646	(0.060)	0.571	(0.090)	0.512	(0.133)
Pittsburg Landing	29 Jun	1,230	0.381	(0.142)	0.556	(0.166)	0.200	(0.179)
Billy Creek	29 Jun	1,246	0.636	(0.087)	0.822	(0.094)	0.857	(0.132)
Pittsburg Landing	6 Jul	1,244	0.579	(0.147)	0.500	(0.177)	NA	NA
Billy Creek	6 Jul	1,241	0.730	(0.118)	0.444	(0.166)	NA	NA
2001								
Pittsburg Landing	23 May	1,246	0.647	(0.054)	0.695	(0.085)	0.278	(0.163)
Billy Creek	23 May	1,248	0.675	(0.027)	0.559	(0.045)	0.338	(0.060)
Pittsburg Landing	30 May	1,244	0.620	(0.091)	0.333	(0.157)	0.636	(0.208)
Billy Creek	30 May	1,248	0.673	(0.033)	0.559	(0.054)	0.342	(0.073)
Pittsburg Landing	6 Jun	1,247	0.433	(0.136)	0.524	(0.248)	0.500	(0.354)
Billy Creek	6 Jun	1,246	0.593	(0.065)	0.427	(0.114)	0.366	(0.200)
Pittsburg Landing	13 Jun	1,247	NA	NA	NA	NA	NA	NA
Billy Creek	13 Jun	1,248	0.624	(0.101)	0.652	(0.206)	NA	NA
Pittsburg Landing	20 Jun	1,243	NA	NA	NA	NA	NA	NA
Billy Creek	20 Jun	1,245	0.421	(0.176)	NA	NA	NA	NA
Pittsburg Landing	27 Jun	1,250	NA	NA	NA	NA	NA	NA
Billy Creek	27 Jun	1,250	NA	NA	NA	NA	NA	NA

Table 6. Estimated survival probabilities for subyearling fall chinook salmon PIT tagged at Lyons Ferry Hatchery and released in free-flowing sections of the Snake and Clearwater Rivers 1998-2001. Estimates based on the Single-Release Model. Standard errors in parentheses.

Release site	Date	Number released	Release to Lower Granite Dam		Lower Granite Dam to Little Goose Dam		Little Goose Dam to Lower Monumental Dam	
				1998				
Pittsburg Landing	2 Jun	1,277	0.502	(0.021)	0.763	(0.034)	0.904	(0.057)
Billy Creek	2 Jun	1,262	0.545	(0.020)	0.768	(0.032)	0.942	(0.061)
Big Canyon Creek	2 Jun	1,254	0.516	(0.022)	0.709	(0.036)	0.949	(0.068)
Pittsburg Landing	9 Jun	1,274	0.512	(0.020)	0.768	(0.035)	0.963	(0.075)
Billy Creek	9 Jun	1,273	0.517	(0.021)	0.719	(0.034)	1.042	(0.082)
Big Canyon Creek	9 Jun	1,274	0.595	(0.021)	0.799	(0.037)	0.798	(0.060)
Pittsburg Landing	16 Jun	1,251	0.480	(0.021)	0.740	(0.038)	0.875	(0.067)
Billy Creek	16 Jun	1,261	0.486	(0.021)	0.754	(0.040)	0.806	(0.063)
Big Canyon Creek	16 Jun	1,271	0.487	(0.021)	0.709	(0.036)	0.966	(0.077)
Pittsburg Landing	23 Jun	1,279	0.236	(0.020)	0.655	(0.066)	0.822	(0.116)
Billy Creek	23 Jun	1,259	0.284	(0.018)	0.714	(0.050)	0.880	(0.092)
Big Canyon Creek	23 Jun	1,264	0.407	(0.021)	0.697	(0.043)	0.836	(0.079)
Pittsburg Landing	30 Jun	1,273	0.165	(0.017)	0.566	(0.069)	0.909	(0.149)
Billy Creek	30 Jun	1,249	0.249	(0.020)	0.656	(0.070)	0.980	(0.194)
Big Canyon Creek	30 Jun	1,254	0.382	(0.029)	0.498	(0.047)	0.862	(0.101)
Billy Creek	7 Jul	1,266	0.237	(0.022)	0.544	(0.064)	0.794	(0.122)
Big Canyon Creek	7 Jul	1,288	0.248	(0.025)	0.460	(0.058)	0.800	(0.126)

Table 6. Continued.

Release site	Date	Number released	Release to Lower Granite Dam		Lower Granite Dam to Little Goose Dam		Little Goose Dam to Lower Monumental Dam	
1999								
Pittsburg Landing	1 Jun	1,239	0.478	(0.030)	0.713	(0.062)	0.695	(0.086)
Asotin	1 Jun	1,225	0.394	(0.028)	0.538	(0.049)	0.770	(0.102)
Big Canyon Creek	1 Jun	1,228	0.375	(0.028)	0.621	(0.060)	0.917	(0.156)
Pittsburg Landing	8 Jun	1,249	0.449	(0.025)	0.630	(0.050)	1.012	(0.163)
Asotin	8 Jun	1,235	0.347	(0.022)	0.645	(0.049)	1.179	(0.172)
Big Canyon Creek	8 Jun	1,247	0.285	(0.024)	0.553	(0.060)	1.052	(0.200)
Pittsburg Landing	15 Jun	1,249	0.250	(0.019)	0.570	(0.066)	1.145	(0.354)
Asotin	15 Jun	1,236	0.283	(0.022)	0.470	(0.049)	0.875	(0.134)
Big Canyon Creek	15 Jun	1,240	0.250	(0.021)	0.503	(0.054)	1.002	(0.189)
Pittsburg Landing	22 Jun	1,256	0.269	(0.019)	0.513	(0.052)	0.832	(0.130)
Asotin	22 Jun	1,251	0.220	(0.019)	0.437	(0.062)	0.967	(0.285)
Big Canyon Creek	22 Jun	1,251	0.198	(0.018)	0.477	(0.065)	0.697	(0.120)
Pittsburg Landing	29 Jun	1,238	0.080	(0.012)	0.428	(0.104)	0.550	(0.154)
Asotin	29 Jun	1,241	0.140	(0.017)	0.465	(0.116)	0.593	(0.252)
Big Canyon Creek	29 Jun	1,255	0.034	(0.006)	0.527	(0.142)	NA	NA
Pittsburg Landing	6 Jul	1,249	0.070	(0.041)	NA	NA	NA	NA
Asotin	6 Jul	1,249	0.072	(0.014)	0.320	(0.140)	NA	NA
Big Canyon Creek	6 Jul	1,244	0.014	(0.009)	0.125	(0.117)	NA	NA

Table 6. Continued.

Release site	Date	Number released	Release to Lower Granite Dam		Lower Granite Dam to Little Goose Dam		Little Goose Dam to Lower Monumental Dam	
2000								
Pittsburg Landing	1 Jun	1,241	0.151	(0.012)	0.795	(0.061)	0.875	(0.131)
Billy Creek	1 Jun	1,239	0.355	(0.017)	0.776	(0.047)	0.700	(0.080)
Pittsburg Landing	8 Jun	1,225	0.043	(0.009)	0.599	(0.170)	0.584	(0.229)
Billy Creek	8 Jun	1,234	0.193	(0.013)	0.833	(0.084)	0.815	(0.212)
Pittsburg Landing	15 Jun	1,249	0.087	(0.011)	0.648	(0.108)	0.715	(0.259)
Billy Creek	15 Jun	1,243	0.161	(0.014)	0.702	(0.093)	0.836	(0.248)
Pittsburg Landing	22 Jun	1,238	0.024	(0.007)	0.444	(0.179)	NA	NA
Billy Creek	22 Jun	1,236	0.099	(0.011)	0.704	(0.110)	0.621	(0.169)
Pittsburg Landing	29 Jun	1,230	0.034	(0.012)	0.369	(0.162)	1.736	(1.393)
Billy Creek	29 Jun	1,246	0.053	(0.008)	0.540	(0.103)	0.627	(0.134)
Pittsburg Landing	6 Jul	1,244	0.015	(0.004)	0.750	(0.237)	NA	NA
Billy Creek	6 Jul	1,241	0.025	(0.005)	0.618	(0.201)	NA	NA

Table 6. Continued.

Release site	Date	Number released	Release to Lower Granite Dam		Lower Granite Dam to Little Goose Dam		Little Goose Dam to Lower Monumental Dam	
2001								
Pittsburg Landing	23 May	1,246	0.113	(0.011)	0.716	(0.093)	0.865	(0.492)
Billy Creek	23 May	1,248	0.410	(0.018)	0.829	(0.063)	0.592	(0.102)
Pittsburg Landing	30 May	1,244	0.049	(0.008)	1.112	(0.501)	0.167	(0.095)
Billy Creek	30 May	1,248	0.289	(0.016)	0.828	(0.076)	0.598	(0.125)
Pittsburg Landing	6 Jun	1,247	0.020	(0.006)	0.897	(0.441)	0.300	(0.242)
Billy Creek	6 Jun	1,246	0.121	(0.014)	0.736	(0.193)	0.401	(0.230)
Pittsburg Landing	13 Jun	1,247	0.006[a]	NA	NA	NA	NA	NA
Billy Creek	13 Jun	1,248	0.050	(0.009)	0.533	(0.182)	NA	NA
Pittsburg Landing	20 Jun	1,243	0.009[b]	NA	NA	NA	NA	NA
Billy Creek	20 Jun	1,245	0.032	(0.013)	NA	NA	NA	NA
Pittsburg Landing	27 Jun	1,250	0.002[c]	NA	NA	NA	NA	NA
Billy Creek	27 Jun	1,250	0.003[d]	NA	NA	NA	NA	NA

a. estimated using daily Lower Granite Dam (LGR) detection probability estimates: 5 detections expanded to 7.26 passing LGR.
b. estimated using daily LGR detection probability estimates: 7 detections expanded to 11.78 passing LGR.
c. estimated using daily LGR detection probability estimates: 2 detections expanded to 3.05 passing LGR.
d. estimated using daily LGR detection probability estimates: 4 detections expanded to 4.26 passing LGR.

Table 7. Estimated survival and detection probabilities for Lower Granite Dam weekly passage groups of PIT-tagged subyearling fall chinook salmon, 1998-2001.

Lower Granite Dam passage dates	N	Survival estimates: Lower Granite to Little Goose Dam	Survival estimates: Little Goose to Lower Monumental Dam	Survival estimates: Lower Granite to Lower Monumental Dam	Detection: Little Goose Dam	Detection: Lower Monumental Dam
1998						
18-24 May[a]	30	0.767 (0.237)	0.713 (0.296)	0.547 (0.122)	0.348 (0.142)	0.545 (0.150)
25-31 May[a]	116	0.760 (0.088)	0.919 (0.193)	0.698 (0.125)	0.465 (0.072)	0.387 (0.087)
1-7 Jun[a]	63	0.729 (0.094)	1.0[b] (0.845)	1.0[b] (0.607)	0.457 (0.088)	0.300 (0.145)
8-14 Jun	60	0.756 (0.152)	0.805 (0.244)	0.608 (0.135)	0.375 (0.101)	0.583 (0.142)
15-21 Jun	93	0.777 (0.050)	1.0[b] (0.111)	0.799 (0.091)	0.733 (0.058)	0.613 (0.088)
22-28 Jun	355	0.805 (0.030)	1.0[b] (0.085)	0.808 (0.067)	0.686 (0.033)	0.488 (0.050)
29 Jun-5 Jul	510	0.838 (0.026)	0.858 (0.054)	0.718 (0.044)	0.698 (0.028)	0.551 (0.040)
6-12 Jul	5,292	0.832 (0.009)	0.918 (0.021)	0.764 (0.017)	0.633 (0.009)	0.473 (0.013)
13-19 Jul	6,073	0.751 (0.008)	0.936 (0.020)	0.703 (0.015)	0.641 (0.009)	0.439 (0.011)
20-26 Jul	2,334	0.748 (0.016)	0.892 (0.038)	0.667 (0.027)	0.578 (0.016)	0.367 (0.018)
27 Jul-2 Aug	1,422	0.829 (0.019)	0.943 (0.045)	0.782 (0.035)	0.565 (0.018)	0.386 (0.022)
3-9 Aug	1,304	0.777 (0.018)	0.995 (0.046)	0.772 (0.035)	0.628 (0.019)	0.420 (0.024)
10-16 Aug	1,166	0.665 (0.026)	0.929 (0.066)	0.618 (0.040)	0.464 (0.024)	0.389 (0.030)
17-23 Aug	370	0.609 (0.048)	0.857 (0.165)	0.521 (0.096)	0.564 (0.050)	0.341 (0.070)
24-30 Aug	213	0.335 (0.049)	0.613 (0.133)	0.205 (0.043)	0.575 (0.087)	0.588 (0.119)
31 Aug-6 Sep[a]	60	0.331 (0.073)	NA	NA	0.857 (0.132)	NA
7-13 Sep	224	0.327 (0.104)	0.356 (0.215)	0.116 (0.061)	0.410 (0.137)	0.400 (0.219)

Table 7. Continued.

Lower Granite Dam passage dates	N	Survival estimates: Lower Granite to Little Goose Dam	Survival estimates: Little Goose to Lower Monumental Dam	Survival estimates: Lower Granite to Lower Monumental Dam	Detection: Little Goose Dam	Detection: Lower Monumental Dam
1999						
1-7 Jun[a]	43	0.349 (0.127)	0.356 (0.171)	0.124 (0.53)	0.600 (0.219)	0.750 (0.217)
8-14 Jun	339	0.818 (0.069)	0.650 (0.095)	0.532 (0.067)	0.496 (0.053)	0.597 (0.079)
15-21 Jun	436	0.795 (0.030)	0.904 (0.074)	0.719 (0.058)	0.649 (0.032)	0.580 (0.052)
22-28 Jun	407	0.784 (0.030)	0.848 (0.070)	0.665 (0.054)	0.705 (0.032)	0.654 (0.057)
29 Jun-5 Jul	297	0.651 (0.045)	1.0[b] (0.237)	0.774 (0.155)	0.701 (0.051)	0.396 (0.088)
6-12 Jul	244	0.677 (0.063)	1.0[b] (0.986)	1.0[b] (0.665)	0.689 (0.069)	0.167 (0.088)
13-19 Jul	692	0.672 (0.034)	0.943 (0.108)	0.634 (0.069	0.519 (0.032)	0.410 (0.049)
20-26 Jul	1,131	0.622 (0.026)	0.967 (0.093)	0.602 (0.056)	0.546 (0.026)	0.367 (0.038)
27 Jul-2 Aug	811	0.569 (0.028)	0.881 (0.094)	0.501 (0.052)	0.590 (0.032)	0.380 (0.044)
3-9 Aug	835	0.535 (0.025)	0.913 (0.083)	0.489 (0.044)	0.606 (0.031)	0.390 (0.040)
10-16 Aug	576	0.464 (0.038)	0.707 (0.109)	0.329 (0.047)	0.520 (0.047)	0.382 (0.061)
17-23 Aug	322	0.800 (0.213)	0.259 (0.110)	0.208 (0.069)	0.276 (0.078)	0.315 (0.114)
24-30 Aug[a]	265	0.111 (0.027)	NA	NA	0.750 (0.153)	NA

Table 7. Continued.

Lower Granite Dam passage dates	N	Survival estimates: Lower Granite to Little Goose Dam	Survival estimates: Little Goose to Lower Monumental Dam	Survival estimates: Lower Granite to Lower Monumental Dam	Detection: Little Goose Dam	Detection: Lower Monumental Dam
2000						
1-7 Jun[a]	25	0.640 (0.157)	1.0[b] (1.415)	1.0[b] (0.895)	0.500 (0.158)	0.143 (0.132)
8-14 Jun	68	0.952 (0.308)	0.632 (0.274)	0.602 (0.159)	0.201 (0.082)	0.208 (0.083)
15-21 Jun	150	0.964 (0.069)	0.701 (0.089)	0.676 (0.071)	0.539 (0.056)	0.545 (0.070)
22-28 Jun	337	0.765 (0.032)	0.920 (0.079)	0.703 (0.060)	0.706 (0.035)	0.489 (0.050)
29 Jun-5 Jul	1,059	0.702 (0.024)	0.809 (0.074)	0.568 (0.051)	0.689 (0.025)	0.329 (0.034)
6-12 Jul	487	0.649 (0.037)	0.798 (0.135)	0.517 (0.085)	0.687 (0.041)	0.292 (0.055)
13-19 Jul	232	0.832 (0.102)	0.709 (0.227)	0.590 (0.174)	0.487 (0.068)	0.226 (0.075)
20-26 Jul	81	0.725 (0.128)	0.582 (0.178)	0.422 (0.112)	0.477 (0.101)	0.636 (0.169)
27 Jul-2 Aug	105	0.868 (0.177)	0.496 (0.209)	0.431 (0.156)	0.461 (0.106)	0.267 (0.114)
3-9 Aug	166	0.791 (0.079)	0.852 (0.232)	0.674 (0.172)	0.571 (0.068)	0.340 (0.097)
10-16 Aug	91	0.956 (0.261)	0.352 (0.140)	0.337 (0.091)	0.356 (0.110)	0.462 (0.138)
17-23 Aug[a]	49	0.620 (0.108)	NA	NA	0.625 (0.121)	NA
24-30 Aug	103	0.754 (0.103)	0.541 (0.135)	0.408 (0.091)	0.567 (0.090)	0.571 (0.132)
31 Aug-6 Sep	95	0.674 (0.085)	0.978 (0.320)	0.659 (0.210)	0.594 (0.087)	0.367 (0.129)
7-13 Sep	116	0.496 (0.083)	0.730 (0.314)	0.362 (0.151)	0.591 (0.105)	0.429 (0.187)
14-20 Sep[a]	51	0.373 (0.136)	NA	NA	0.526 (0.202)	NA

Table 7. Continued.

Lower Granite Dam passage dates	N	Survival estimates: Lower Granite to Little Goose Dam	Little Goose to Lower Monumental Dam	Lower Granite to Lower Monumental Dam	Detection: Little Goose Dam	Lower Monumental Dam
2001						
1-7 Jun[a]	979	0.787 (0.044)	1.0[b] (0.430)	0.820 (0.328)	0.677 (0.040)	0.273 (0.110)
8-14 Jun	3,047	0.853 (0.028)	0.864 (0.141)	0.737 (0.113)	0.638 (0.022)	0.278 (0.044)
15-21 Jun	318	0.755 (0.043)	0.788 (0.116)	0.595 (0.084)	0.683 (0.044)	0.436 (0.069)
22-28 Jun	559	0.788 (0.037)	0.621 (0.069)	0.490 (0.051)	0.663 (0.036)	0.448 (0.052)
29 Jun-5 Jul	2,298	0.820 (0.026)	0.647 (0.057)	0.530 (0.044)	0.577 (0.021)	0.316 (0.029)
6-12 Jul	1,638	0.716 (0.032)	0.654 (0.086)	0.468 (0.058)	0.563 (0.028)	0.276 (0.037)
13-19 Jul	593	0.595 (0.050)	0.489 (0.108)	0.291 (0.060)	0.601 (0.053)	0.395 (0.087)
20-26 Jul[a]	166	0.427 (0.062)	NA	NA	0.805 (0.103)	NA
27 Jul-2 Aug	148	0.669 (0.144)	0.270 (0.093)	0.181 (0.050)	0.495 (0.114)	0.429 (0.132)
3-9 Aug	166	0.657 (0.115)	0.521 (0.215)	0.342 (0.130)	0.514 (0.098)	0.308 (0.128)
10-16 Aug	866	0.537 (0.044)	0.827 (0.277)	0.444 (0.145)	0.585 (0.050)	0.163 (0.056)
17-23 Aug[a]	159	0.281 (0.090)	NA	NA	0.581 (0.186)	NA
24-30 Aug[a]	94	NA	NA	NA	NA	NA
31 Aug-6 Sep[a]	50	NA	NA	NA	NA	NA
7-13 Sep[a]	25	NA	NA	NA	NA	NA
14-20 Sep[a]	57	0.175 (0.122)	NA	NA	0.500 (0.354)	NA

[a] Group not used in analyses of relations of survival and travel time with river conditions.

[b] Model-based estimate greater than 1.0.

Table 8. Travel times and migration rates between the point of release and Lower Granite Dam for hatchery subyearling fall chinook salmon released at Pittsburg Landing (PL, 173 km), Big Canyon Creek (CW, 108 km), Billy Creek (BC, 92 km), and Asotin (AS, 63 km), 1998-2001.

			Travel time (days)					Migration rate (km/day)				
Release	Date	N	Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
1998												
PL1	2 Jun	298	3.9	36.1	41.9	48.0	112.8	1.5	3.6	4.1	4.8	43.9
PL2	9 Jun	340	18.3	31.4	36.4	46.8	124.1	1.4	3.7	4.7	5.5	9.4
PL3	16 Jun	306	2.8	27.7	32.3	53.0	134.4	1.3	3.3	5.4	6.3	61.3
PL4	23 Jun	123	4.2	22.6	37.6	53.5	112.5	1.5	3.2	4.6	7.6	41.1
PL5	30 Jun	98	7.5	22.0	39.1	67.4	110.6	1.6	2.6	4.4	7.9	23.2
CW1	2 Jun	303	3.9	35.7	41.8	47.7	144.8	0.7	2.3	2.6	3.0	27.7
CW2	9 Jun	387	11.6	31.2	36.3	48.6	139.7	0.8	2.2	3.0	3.5	9.3
CW3	16 Jun	307	4.0	27.6	31.7	50.3	137.5	0.8	2.1	3.4	3.9	26.8
CW4	23 Jun	263	2.8	22.4	38.3	52.5	118.4	0.9	2.1	2.8	4.8	38.2
CW5	30 Jun	201	3.4	16.6	38.8	53.4	104.5	1.0	2.0	2.8	6.5	31.5
CW6	7 Jul	131	5.3	23.8	39.6	70.4	98.4	1.1	1.5	2.7	4.5	20.6
BC1	2 Jun	370	13.4	35.8	41.8	45.7	126.6	0.7	2.0	2.2	2.6	6.9
BC2	9 Jun	319	7.2	29.9	36.1	45.3	123.7	0.7	2.0	2.5	3.1	12.7
BC3	16 Jun	292	3.9	27.3	30.2	45.0	109.7	0.8	2.0	3.0	3.4	23.6
BC4	23 Jun	169	3.1	21.5	36.2	52.3	106.7	0.9	1.8	2.5	4.3	30.2
BC5	30 Jun	139	7.4	23.6	39.8	60.9	107.8	0.9	1.5	2.3	3.9	12.5
BC6	7 Jul	132	4.9	27.5	36.6	70.3	111.0	0.8	1.3	2.5	3.3	18.7

Table 8. Continued.

Release	Date	N	Travel time (days) Min.	20%	Median	80%	Max.	Migration rate (km/day) Min.	20%	Median	80%	Max.
1999												
PL1	1 Jun	219	3.8	19.9	43.3	59.9	87.8	2.0	2.9	4.0	8.7	45.4
PL2	8 Jun	269	5.5	25.5	47.5	61.4	84.4	2.0	2.8	3.6	6.8	31.7
PL3	15 Jun	184	2.6	37.5	48.6	57.6	77.1	2.2	3.0	3.6	4.6	67.1
PL4	22 Jun	206	4.6	32.8	46.3	57.5	70.4	2.5	3.0	3.7	5.3	37.6
PL5	29 Jun	63	5.1	34.2	43.8	57.6	63.1	2.7	3.0	3.9	5.1	33.7
PL6	6 Jul	25	13.8	31.8	39.9	50.3	53.6	3.2	3.4	4.3	5.4	12.5
CW1	1 Jun	180	1.7	16.6	50.8	63.6	89.9	1.2	1.7	2.1	6.5	65.5
CW2	8 Jun	148	3.1	37.2	53.3	65.7	82.9	1.3	1.6	2.0	2.9	34.6
CW3	15 Jun	163	2.9	31.6	49.9	60.5	77.5	1.4	1.8	2.2	3.4	37.4
CW4	22 Jun	148	4.8	36.1	46.5	57.8	69.9	1.5	1.9	2.3	3.0	22.5
CW5	29 Jun	30	22.4	37.1	43.5	54.9	57.8	1.9	2.0	2.5	2.9	4.8
CW6	6 Jul	9	20.9	30.1	33.0	47.6	50.8	2.1	2.3	3.3	3.6	5.2
AS1	1 Jun	198	1.4	13.7	47.0	61.1	85.5	0.7	1.0	1.3	4.6	44.4
AS2	8 Jun	188	1.6	27.2	50.8	63.5	82.8	0.8	1.0	1.2	2.3	38.7
AS3	15 Jun	186	1.4	30.9	50.4	60.9	77.4	0.8	1.0	1.2	2.0	46.7
AS4	22 Jun	176	2.2	35.9	46.5	56.9	70.4	0.9	1.1	1.4	1.8	28.6
AS5	29 Jun	108	2.4	28.8	41.7	52.1	63.1	1.0	1.2	1.5	2.2	26.7
AS6	6 Jul	58	15.7	30.5	37.8	50.5	56.6	1.1	1.2	1.7	2.1	4.0

Table 8. Continued.

Release	Date	N	Travel time (days) Min.	20%	Median	80%	Max.	Migration rate (km/day) Min.	20%	Median	80%	Max.
2000												
PL1	1 Jun	122	20.3	24.8	30.8	34.1	109.5	1.6	5.1	5.6	7.0	8.5
PL2	8 Jun	28	16.5	24.2	27.1	47.9	118.2	1.5	3.6	6.4	7.1	10.5
PL3	15 Jun	60	16.3	24.5	38.7	64.6	116.4	1.5	2.7	4.5	7.1	10.6
PL4	23 Jun	17	17.8	27.3	45.0	69.8	131.7	1.3	2.5	3.8	6.3	9.7
PL5	29 Jun	16	30.5	41.3	60.5	85.0	124.4	1.4	2.0	2.9	4.2	5.7
PL6	6 Jul	11	22.6	35.5	51.9	90.4	114.9	1.5	1.9	3.3	4.9	7.6
BC1	1 Jun	291	13.4	27.8	31.6	39.1	123.3	0.7	2.4	2.9	3.3	6.9
BC2	8 Jun	172	5.1	23.4	26.4	45.2	139.1	0.7	2.0	3.5	3.9	17.9
BC3	15 Jun	128	14.4	20.2	39.8	66.8	138.1	0.7	1.4	2.3	4.6	6.4
BC4	22 Jun	79	11.3	34.4	53.9	75.3	131.6	0.7	1.2	1.7	2.7	8.1
BC5	29 Jun	42	11.3	43.6	65.5	85.2	115.5	0.8	1.1	1.4	2.1	8.2
BC6	6 Jul	23	19.8	48.4	63.2	75.5	108.2	0.9	1.2	1.5	1.9	4.7
2001												
PL1	23 May	91	13.5	21.0	41.0	48.9	127.0	0.7	1.9	2.2	4.4	6.8
PL2	30 May	38	13.6	19.9	34.9	45.9	92.4	1.0	2.0	2.6	4.6	6.8
PL3	6 Jun	11	21.3	28.6	40.7	54.1	74.5	1.2	1.7	2.3	3.2	4.3
PL4	13 Jun	5	21.4	22.8	30.9	45.1	59.1	1.6	2.0	3.0	4.0	4.3
PL5	20 Jun	7	13.9	15.8	20.4	34.6	52.9	1.7	2.7	4.5	5.8	6.6
PL6	27 Jun	2	55.1	61.4	70.9	80.3	86.6	1.1	1.1	1.3	1.5	1.7
BC1	23 May	345	12.7	20.1	40.7	47.9	147.7	1.2	3.6	4.3	8.6	13.6
BC2	30 May	243	8.8	33.5	36.0	45.9	114.7	1.5	3.8	4.8	5.2	19.7
BC3	6 Jun	89	12.4	27.6	31.7	52.0	109.7	1.6	3.3	5.5	6.3	14.0
BC4	13 Jun	39	20.0	20.7	27.0	46.3	89.0	1.9	3.7	6.4	8.4	8.6
BC5	20 Jun	17	13.1	14.8	23.1	53.7	63.7	2.7	3.2	7.5	11.7	13.3
BC6	27 Jun	4	10.1	28.5	43.8	73.6	113.6	1.5	2.4	3.9	6.1	17.1

Table 9. Travel times and migration rates between Lower Granite Dam and Little Goose Dam (60 km) for hatchery subyearling fall chinook salmon released at Pittsburg Landing (PL), Big Canyon Creek (CW), Billy Creek (BC), and Asotin (AS), 1998-2001.

			Travel time (days)					Migration rate (km/day)				
Release	Date	N	Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
						1998						
PL1	2 Jun	145	1.1	2.2	3.0	4.4	19.8	3.0	13.6	19.8	27.3	53.6
PL2	9 Jun	154	1.5	2.4	3.0	4.8	19.1	3.1	12.5	19.8	24.8	39.0
PL3	16 Jun	135	1.6	2.4	3.4	6.8	30.7	2.0	8.9	17.5	25.1	38.2
PL4	23 Jun	40	1.7	2.9	4.1	6.6	24.4	2.5	9.2	14.7	20.6	34.5
PL5	30 Jun	33	2.0	2.6	3.5	7.6	38.4	1.6	7.9	17.1	22.9	30.5
CW1	2 Jun	139	1.5	2.2	2.9	4.8	18.2	3.3	12.4	20.4	27.6	39.0
CW2	9 Jun	180	1.5	2.4	3.3	7.5	43.3	1.4	8.0	18.1	25.3	39.0
CW3	16 Jun	126	1.8	2.6	3.6	7.2	29.1	2.1	8.3	16.9	23.0	34.1
CW4	23 Jun	102	1.5	2.7	3.7	11.6	47.9	1.3	5.2	16.3	22.0	39.7
CW5	30 Jun	59	2.1	3.1	4.1	8.3	93.0	0.6	7.2	14.5	19.2	29.1
CW6	7 Jul	35	2.3	3.2	4.8	8.3	27.9	2.2	7.2	12.6	18.6	26.5
BC1	2 Jun	169	1.3	2.2	3.0	5.2	49.8	1.2	11.6	20.0	27.9	45.8
BC2	9 Jun	141	1.2	2.2	3.2	5.9	16.3	3.7	10.2	18.8	27.8	50.0
BC3	16 Jun	126	1.5	2.2	3.2	6.5	25.9	2.3	9.2	18.8	27.0	40.5
BC4	23 Jun	68	1.6	2.7	3.5	6.7	46.4	1.3	8.9	17.0	22.1	38.2
BC5	30 Jun	55	1.5	2.7	4.2	8.0	34.0	1.8	7.5	14.4	22.4	41.4
BC6	7 Jul	33	1.7	2.2	4.1	9.3	22.7	2.6	6.5	14.7	27.1	35.7

Table 9. Continued.

Release	Date	N	Travel time (days) Min.	20%	Median	80%	Max.	Migration rate (km/day) Min.	20%	Median	80%	Max.
					1999							
PL1	1 Jun	65	1.2	3.2	6.5	22.4	66.6	0.9	2.7	9.2	18.5	50.8
PL2	8 Jun	83	1.6	3.1	6.0	11.4	45.4	1.3	5.3	10.1	19.5	38.2
PL3	15 Jun	48	2.1	3.1	5.9	18.6	37.6	1.6	3.2	10.2	19.2	29.0
PL4	22 Jun	56	1.6	4.2	7.1	12.9	34.7	1.7	4.6	8.4	14.4	38.0
PL5	29 Jun	11	2.4	4.2	7.7	14.0	34.0	1.8	4.3	7.8	14.2	24.6
PL6	6 Jul	2	15.7	16.1	16.6	17.1	17.5	3.4	3.5	3.6	3.7	3.8
CW1	1 Jun	57	1.6	3.0	7.7	27.2	61.2	1.0	2.2	7.8	19.7	38.0
CW2	8 Jun	38	1.7	3.0	4.9	14.1	57.1	1.1	4.3	12.2	20.3	34.9
CW3	15 Jun	50	1.9	3.5	6.8	17.4	64.1	0.9	3.4	8.8	17.3	32.3
CW4	22 Jun	32	2.2	4.0	6.3	15.7	25.2	2.4	3.8	9.5	15.0	27.4
CW5	29 Jun	9	1.9	4.6	5.9	12.2	24.2	2.5	4.9	10.2	13.2	30.9
CW6	6 Jul	1	3.8	3.8	3.8	3.8	3.8	15.9	15.9	15.9	15.9	15.9
AS1	1 Jun	61	1.9	2.8	4.6	18.1	53.0	1.1	3.3	13.0	21.2	32.4
AS2	8 Jun	73	1.7	3.3	5.7	11.0	43.2	1.4	5.4	10.5	18.4	35.1
AS3	15 Jun	51	1.5	3.2	5.5	18.3	51.6	1.2	3.3	11.0	18.6	40.5
AS4	22 Jun	37	2.4	3.8	5.3	10.4	28.5	2.1	5.8	11.3	15.9	25.2
AS5	29 Jun	19	1.9	3.9	5.6	10.9	29.8	2.0	5.5	10.7	15.3	32.3
AS6	6 Jul	8	3.2	3.7	5.8	11.1	19.2	3.1	5.4	10.3	16.3	18.8

Table 9. Continued.

Release	Date	N	Travel time (days) Min.	20%	Median	80%	Max.	Migration rate (km/day) Min.	20%	Median	80%	Max.
2000												
PL1	1 Jun	62	1.8	3.3	5.9	11.7	45.7	1.3	5.1	10.1	18.2	33.7
PL2	8 Jun	7	2.3	3.3	6.4	18.2	33.4	1.8	3.3	9.4	18.0	26.3
PL3	15 Jun	21	3.3	5.6	11.2	25.1	76.3	0.8	2.4	5.4	10.7	18.3
PL4	23 Jun	4	3.7	6.1	10.8	15.9	18.8	3.2	3.8	5.5	9.8	16.1
PL5	29 Jun	4	3.6	3.9	8.9	25.9	44.1	1.4	2.3	6.7	15.4	16.8
PL6	6 Jul	1	12.7	12.7	12.7	12.7	12.7	4.7	4.7	4.7	4.7	4.7
BC1	1 Jun	131	2.3	3.4	6.3	17.4	41.6	1.4	3.5	9.5	17.8	26.4
BC2	8 Jun	70	2.5	3.6	8.1	15.9	75.2	0.8	3.8	7.4	16.8	24.0
BC3	15 Jun	37	2.0	3.3	6.0	14.6	96.6	0.6	4.1	10.1	18.1	29.9
BC4	22 Jun	29	2.7	4.6	9.7	19.6	38.3	1.6	3.1	6.2	13.1	22.1
BC5	29 Jun	14	3.9	5.8	10.1	12.5	15.5	3.9	4.8	5.9	10.4	15.5
BC6	6 Jul	5	3.8	8.2	9.6	11.4	13.8	4.4	5.3	6.3	7.3	15.7
2001												
PL1	23 May	42	2.0	4.3	14.2	25.0	61.8	1.0	2.4	4.2	14.0	30.5
PL2	30 May	13	2.3	3.2	9.3	17.2	22.0	2.7	3.5	6.5	18.8	26.7
PL3	6 Jun	3	4.7	9.6	17.0	17.2	17.4	3.5	3.5	3.5	6.2	12.7
PL4	13 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL5	20 Jun	4	3.1	4.6	5.8	13.6	25.1	2.4	4.4	10.3	12.9	19.4
PL6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC1	23 May	149	1.8	5.1	12.7	24.6	87.1	0.7	2.4	4.7	11.7	32.6
BC2	30 May	99	1.7	3.9	9.4	24.5	68.0	0.9	2.4	6.4	15.4	36.1
BC3	6 Jun	26	2.6	5.3	9.0	13.4	53.5	1.1	4.5	6.7	11.4	23.1
BC4	13 Jun	12	2.6	5.9	11.1	28.8	37.9	1.6	2.1	5.4	10.1	22.8
BC5	20 Jun	3	5.9	11.8	20.6	33.9	42.8	1.4	1.8	2.9	5.1	10.3
BC6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 10. Travel times and migration rates between Little Goose Dam and Lower Monumental Dam (46 km) for hatchery subyearling fall chinook salmon released at Pittsburg Landing (PL), Big Canyon Creek (CW), Billy Creek (BC), and Asotin (AS), 1998-2001.

			Travel time (days)					Migration rate (km/day)				
Release	Date	N	Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
						1998						
PL1	2 Jun	132	1.3	2.0	3.1	6.5	19.2	2.4	7.0	14.6	23.0	35.1
PL2	9 Jun	101	1.2	2.1	3.0	6.6	13.0	3.5	7.0	15.3	22.0	37.7
PL3	16 Jun	81	1.2	2.4	3.9	7.9	26.4	1.7	5.8	11.8	18.9	37.7
PL4	23 Jun	30	1.5	2.8	3.3	8.7	26.5	1.7	5.3	14.0	16.6	30.5
PL5	30 Jun	24	1.5	2.2	3.3	6.2	13.4	3.4	7.5	14.1	20.5	30.9
CW1	2 Jun	114	1.2	2.1	3.2	6.0	20.3	2.3	7.6	14.5	22.2	39.0
CW2	9 Jun	111	1.5	2.0	3.2	5.8	12.9	3.6	8.0	14.2	22.8	30.3
CW3	16 Jun	99	1.6	2.3	3.8	7.1	28.4	1.6	6.5	12.1	20.3	28.0
CW4	23 Jun	65	1.7	2.7	4.0	6.1	19.0	2.4	7.6	11.6	17.3	26.7
CW5	30 Jun	41	1.8	3.1	4.0	6.0	34.8	1.3	7.7	11.5	15.0	25.4
CW6	7 Jul	30	2.1	3.2	5.1	10.2	37.8	1.2	4.5	9.1	14.3	21.7
BC1	2 Jun	129	1.3	2.1	3.1	6.5	20.9	2.2	7.1	14.7	22.4	34.6
BC2	9 Jun	115	1.1	2.0	3.1	7.0	41.4	1.1	6.6	15.0	22.5	40.7
BC3	16 Jun	101	1.6	2.2	3.2	7.1	29.2	1.6	6.4	14.3	20.5	29.7
BC4	23 Jun	47	1.4	2.8	5.0	8.3	26.8	1.7	5.5	9.1	16.3	33.6
BC5	30 Jun	30	1.5	2.1	3.9	5.9	36.0	1.3	7.8	11.8	22.3	30.5
BC6	7 Jul	31	1.8	2.7	3.9	6.2	27.3	1.7	7.4	11.8	17.2	25.1

Table 10. Continued.

Release	Date	N	Travel time (days) Min.	20%	Median	80%	Max.	Migration rate (km/day) Min.	20%	Median	80%	Max.
					1999							
PL1	1 Jun	66	1.2	2.5	4.2	7.3	21.4	2.1	6.3	10.8	18.5	37.1
PL2	8 Jun	53	1.2	2.1	3.7	6.7	24.7	1.9	6.9	12.6	21.5	37.1
PL3	15 Jun	21	1.2	2.1	4.4	9.3	28.8	1.6	5.0	10.6	21.9	39.7
PL4	22 Jun	37	1.5	2.9	4.0	7.0	19.0	2.4	6.6	11.6	16.1	31.7
PL5	29 Jun	6	2.7	3.5	4.4	6.8	8.1	5.7	6.7	10.5	13.1	16.9
PL6	6 Jul	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CW1	1 Jun	47	1.3	2.7	4.1	13.9	27.6	1.7	3.3	11.3	17.1	34.8
CW2	8 Jun	41	1.5	2.8	4.9	8.6	25.0	1.8	5.3	9.5	16.3	30.9
CW3	15 Jun	33	1.6	2.8	5.9	7.7	13.8	3.3	6.0	7.9	16.6	28.8
CW4	22 Jun	19	2.0	3.1	3.5	7.4	9.1	5.0	6.2	13.2	14.8	23.5
CW5	29 Jun	3	2.3	2.5	2.8	3.0	3.2	14.6	15.3	16.4	18.2	19.7
CW6	6 Jul	1	3.9	3.9	3.9	3.9	3.9	11.7	11.7	11.7	11.7	11.7
AS1	1 Jun	62	1.2	2.4	3.9	7.9	36.0	1.3	5.8	11.9	19.3	38.7
AS2	8 Jun	58	1.4	3.0	4.8	9.5	24.9	1.8	4.9	9.6	15.3	33.1
AS3	15 Jun	35	1.4	3.4	5.9	8.3	29.3	1.6	5.5	7.9	13.6	32.6
AS4	22 Jun	18	1.2	2.5	4.1	12.8	63.0	0.7	3.6	11.3	18.5	37.1
AS5	29 Jun	5	2.7	3.4	4.1	7.5	9.5	4.9	6.1	11.4	13.5	17.2
AS6	6 Jul	1	17.9	17.9	17.9	17.9	17.9	2.6	2.6	2.6	2.6	2.6

Table 10. Continued.

Release	Date	N	Travel time (days)					Migration rate (km/day)				
			Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
2000												
PL1	1 Jun	29	1.7	3.1	4.9	22.4	78.9	0.6	2.1	9.3	15.1	27.4
PL2	8 Jun	4	2.3	2.7	8.5	29.8	53.4	0.9	1.5	5.4	17.0	19.8
PL3	15 Jun	11	2.8	3.2	12.5	27.6	60.8	0.8	1.7	3.7	14.2	16.7
PL4	23 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL5	29 Jun	3	5.0	6.2	8.0	17.4	23.7	1.9	2.6	5.7	7.4	9.2
PL6	6 Jul	4	2.6	4.5	6.6	8.0	8.9	5.2	5.7	6.9	10.2	17.4
BC1	1 Jun	51	2.2	3.1	7.3	26.1	73.3	0.6	1.8	6.3	14.9	21.0
BC2	8 Jun	23	2.3	3.6	7.4	18.5	37.7	1.2	2.5	6.3	12.7	20.0
BC3	15 Jun	14	2.1	4.1	11.1	24.7	51.1	0.9	1.9	4.2	11.3	22.0
BC4	22 Jun	11	3.5	4.9	8.8	37.0	75.7	0.6	1.2	5.2	9.4	13.0
BC5	29 Jun	11	3.0	4.4	9.6	18.4	39.4	1.2	2.5	4.8	10.5	15.2
BC6	6 Jul	4	5.1	6.2	7.4	9.0	10.6	4.3	5.1	6.2	7.4	9.1
2001												
PL1	23 May	15	2.9	3.2	10.0	16.0	25.7	1.8	2.9	4.6	14.2	16.0
PL2	30 May	2	4.1	15.1	31.6	48.2	59.2	0.8	1.0	1.5	3.0	11.2
PL3	6 Jun	2	12.4	29.8	56.0	82.1	99.5	0.5	0.6	0.8	1.5	3.7
PL4	13 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL5	20 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC1	23 May	40	1.8	4.7	10.6	15.6	62.7	0.7	3.0	4.4	9.8	25.1
BC2	30 May	29	3.2	5.1	9.6	18.5	44.1	1.0	2.5	4.8	8.9	14.5
BC3	6 Jun	5	4.6	5.6	9.7	12.2	20.9	2.2	3.8	4.8	8.3	9.9
BC4	13 Jun	2	8.5	14.9	24.6	34.3	40.8	1.1	1.3	1.9	3.1	5.4
BC5	20 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 11. Travel times and migration rates between Lower Monumental Dam and McNary Dam (119 km) for hatchery subyearling fall chinook salmon released at Pittsburg Landing (PL), Big Canyon Creek (CW), Billy Creek (BC), and Asotin (AS), 1998-2001.

			Travel time (days)					Migration rate (km/day)				
Release	Date	N	Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
						1998						
PL1	2 Jun	82	2.3	3.1	3.9	5.6	13.7	8.7	21.4	30.4	38.9	51.3
PL2	9 Jun	65	2.7	3.2	4.1	5.9	12.8	9.3	20.2	29.1	37.2	43.9
PL3	16 Jun	60	2.1	3.0	3.8	5.9	105.2	1.1	20.1	31.3	39.1	56.7
PL4	23 Jun	22	2.9	3.3	4.4	5.5	13.2	9.0	21.5	27.3	36.0	41.5
PL5	30 Jun	15	2.6	3.3	4.4	6.0	11.5	10.4	19.7	27.2	35.7	46.3
CW1	2 Jun	74	2.3	3.1	3.6	5.2	113.8	1.0	23.1	33.0	37.9	52.0
CW2	9 Jun	76	2.5	3.1	4.1	5.6	10.3	11.6	21.3	29.4	38.1	48.6
CW3	16 Jun	60	2.2	3.0	3.5	4.9	14.8	8.1	24.5	34.5	39.3	54.3
CW4	23 Jun	45	2.8	3.2	4.4	7.0	29.8	4.0	17.0	27.4	37.2	43.3
CW5	30 Jun	31	2.8	3.7	5.0	8.3	13.0	9.2	14.4	23.8	32.5	43.1
CW6	7 Jul	16	3.1	4.7	7.4	9.5	33.7	3.5	12.5	16.1	25.1	38.1
BC1	2 Jun	85	2.0	3.1	3.7	4.8	12.1	9.8	24.8	32.2	38.6	60.4
BC2	9 Jun	62	2.4	3.1	3.6	5.1	14.0	8.5	23.6	33.0	38.6	50.2
BC3	16 Jun	67	2.7	3.4	4.1	5.6	14.0	8.5	21.1	28.8	35.0	44.4
BC4	23 Jun	34	2.4	3.4	4.6	7.3	69.4	1.7	16.4	26.0	35.3	49.6
BC5	30 Jun	14	2.8	3.9	4.2	6.8	11.7	10.2	17.4	28.5	30.2	42.7
BC6	7 Jul	19	3.5	4.1	6.6	9.6	14.9	8.0	12.4	17.9	29.4	34.1

Table 11. Continued.

Release	Date	N	Travel time (days)					Migration rate (km/day)				
			Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
							1998					
PL1	1 Jun	19	2.0	3.1	4.2	7.1	29.1	4.1	16.8	28.2	37.9	58.9
PL2	8 Jun	14	2.7	3.2	4.5	7.0	10.5	11.4	17.0	26.7	37.5	43.6
PL3	15 Jun	7	2.3	3.1	3.6	6.3	7.3	16.3	18.8	33.0	38.6	50.9
PL4	22 Jun	16	2.4	2.9	3.5	5.7	8.6	13.8	20.8	33.7	40.5	49.8
PL5	29 Jun	6	2.7	3.3	3.5	5.1	9.5	12.6	23.3	34.4	36.0	44.9
PL6	6 Jul	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CW1	1 Jun	13	2.6	4.0	5.5	8.6	17.0	7.0	13.8	21.8	29.5	46.1
CW2	8 Jun	9	2.6	3.4	4.3	10.1	18.2	6.5	11.8	27.5	35.1	45.1
CW3	15 Jun	14	3.1	3.3	4.0	6.6	10.9	11.0	17.9	29.5	36.0	39.0
CW4	22 Jun	14	2.6	3.2	4.8	9.7	16.0	7.4	12.2	24.7	37.5	45.6
CW5	29 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CW6	6 Jul	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
AS1	1 Jun	15	2.9	3.2	5.0	7.7	10.1	11.8	15.4	24.0	36.8	41.3
AS2	8 Jun	18	2.8	3.7	4.9	7.4	17.0	7.0	16.0	24.2	31.9	42.0
AS3	15 Jun	16	2.9	3.2	4.3	5.4	19.0	6.3	22.0	27.7	37.8	41.0
AS4	22 Jun	5	3.3	3.7	5.0	5.5	6.1	19.5	21.8	23.8	32.4	35.7
AS5	29 Jun	4	3.3	4.0	5.2	6.3	6.7	17.9	18.9	22.8	30.1	35.8
AS6	6 Jul	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 11. Continued.

Release	Date	N	Travel time (days)					Migration rate (km/day)				
			Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
2000												
PL1	1 Jun	17	2.6	3.7	4.6	7.0	10.0	11.9	17.0	25.9	32.3	46.1
PL2	8 Jun	3	5.2	5.5	6.1	11.5	15.1	7.9	10.4	19.5	21.5	23.1
PL3	15 Jun	4	3.6	4.7	6.8	12.9	19.8	6.0	9.2	17.4	25.5	33.2
PL4	23 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL5	29 Jun	1	5.2	5.2	5.2	5.2	5.2	22.9	22.9	22.9	22.9	22.9
PL6	6Jul	2	13.4	21.2	32.9	44.6	52.4	2.3	2.7	3.6	5.6	8.9
BC1	1 Jun	33	3.2	4.5	5.5	11.8	39.1	3.0	10.1	21.7	26.6	37.0
BC2	8 Jun	9	3.0	4.3	5.3	6.6	8.3	14.4	17.9	22.5	27.5	39.8
BC3	15 Jun	7	3.3	4.8	7.9	12.9	23.3	5.1	9.2	15.0	24.7	36.5
BC4	22 Jun	7	4.6	8.7	16.1	31.5	41.2	2.9	3.8	7.4	13.7	25.6
BC5	29 Jun	6	6.6	7.1	8.8	15.5	58.4	2.0	7.7	13.5	16.8	18.1
BC6	6 Jul	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2001												
PL1	23 May	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL2	30 May	2	6.5	7.4	8.9	10.3	11.2	10.6	11.6	13.4	16.0	18.3
PL3	6 Jun	1	7.3	7.3	7.3	7.3	7.3	16.3	16.3	16.3	16.3	16.3
PL4	13 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL5	20 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC1	23 May	16	4.8	9.1	14.7	22.0	45.7	2.6	5.4	8.1	13.1	24.7
BC2	30 May	8	4.2	7.8	13.6	35.3	56.6	2.1	3.4	8.7	15.3	28.1
BC3	6 Jun	2	10.1	12.2	15.4	18.6	20.7	5.8	6.4	7.7	9.8	11.8
BC4	13 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC5	20 Jun	1	8.7	8.7	8.7	8.7	8.7	13.7	13.7	13.7	13.7	13.7
BC6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 12. Travel times and migration rates between the point of release and McNary Dam for hatchery subyearling fall chinook salmon released at Pittsburg Landing (PL, 398 km), Big Canyon Creek (CW, 333 km), Billy Creek (BC, 317 km), and Asotin (AS, 288 km), 1998-2001.

			Travel time (days)					Migration rate (km/day)				
Release	Date	N	Min.	20%	Median	80%	Max.	Min.	20%	Median	80%	Max.
1998												
PL1	2 Jun	171	18.8	49.2	53.7	61.0	110.4	3.6	6.5	7.4	8.1	21.2
PL2	9 Jun	163	34.7	44.5	50.2	59.1	86.5	4.6	6.7	7.9	8.9	11.5
PL3	16 Jun	160	16.1	38.3	45.3	59.8	170.0	2.3	6.7	8.8	10.4	24.8
PL4	23 Jun	53	29.8	39.9	51.9	58.5	170.8	2.3	6.8	7.7	10.0	13.3
PL5	30 Jun	35	21.2	35.4	47.5	56.2	160.9	2.5	7.1	8.4	11.3	18.8
CW1	2 Jun	173	15.1	48.3	52.6	59.7	191.2	1.7	5.6	6.3	6.9	22.0
CW2	9 Jun	173	35.3	42.8	46.6	56.1	156.9	2.1	5.9	7.1	7.8	9.4
CW3	16 Jun	144	29.6	38.5	45.7	61.9	92.6	3.6	5.4	7.3	8.7	11.3
CW4	23 Jun	100	24.5	37.5	47.2	56.8	114.9	2.9	5.9	7.1	8.9	13.6
CW5	30 Jun	70	17.1	37.4	48.6	55.0	153.8	2.2	6.1	6.8	8.9	19.4
CW6	7 Jul	39	25.4	36.4	43.4	55.1	125.8	2.6	6.0	7.7	9.1	13.1
BC1	2 Jun	195	38.9	46.8	52.7	58.9	88.0	3.6	5.4	6.0	6.8	8.2
BC2	9 Jun	162	33.1	43.0	46.7	55.0	75.8	4.2	5.8	6.8	7.4	9.6
BC3	16 Jun	135	28.7	37.3	43.6	55.6	72.0	4.4	5.7	7.3	8.5	11.0
BC4	23 Jun	85	21.5	37.1	49.6	58.7	148.8	2.1	5.4	6.4	8.5	14.8
BC5	30 Jun	42	23.1	33.3	47.1	53.4	87.8	3.6	5.9	6.7	9.5	13.7
BC6	7 Jul	40	25.2	40.4	43.7	49.7	91.9	3.5	6.4	7.3	7.8	12.6

Table 12. Continued.

Release	Date	N	Travel time (days) Min.	20%	Median	80%	Max.	Migration rate (km/day) Min.	20%	Median	80%	Max.
							1999					
PL1	1 Jun	45	15.6	33.1	58.7	70.0	110.8	3.6	5.7	6.8	12.0	25.6
PL2	8 Jun	51	23.6	36.5	58.7	74.8	88.7	4.5	5.3	6.8	10.9	16.9
PL3	15 Jun	31	45.7	53.2	60.5	74.2	104.1	3.8	5.4	6.6	7.5	8.7
PL4	22 Jun	36	40.1	51.9	58.5	67.5	86.6	4.6	5.9	6.8	7.7	9.9
PL5	29 Jun	11	41.6	48.9	53.1	68.1	79.0	5.0	5.8	7.5	8.1	9.6
PL6	6 Jul	1	45.8	45.8	45.8	45.8	45.8	8.7	8.7	8.7	8.7	8.7
CW1	1 Jun	41	27.0	33.4	60.9	78.7	114.8	2.9	4.2	5.5	10.0	12.4
CW2	8 Jun	29	22.3	49.6	63.5	78.4	90.9	3.7	4.2	5.2	6.7	15.0
CW3	15 Jun	33	21.6	55.2	64.0	70.8	98.8	3.4	4.7	5.2	6.0	15.4
CW4	22 Jun	33	39.5	49.9	59.3	65.6	81.7	4.1	5.1	5.6	6.7	8.4
CW5	29 Jun	4	41.5	45.2	51.8	62.3	71.8	4.6	5.3	6.4	7.4	8.0
CW6	6 Jul	1	80.0	80.0	80.0	80.0	80.0	4.2	4.2	4.2	4.2	4.2
AS1	1 Jun	37	26.6	37.2	68.2	73.8	82.9	3.5	3.9	4.2	7.7	10.8
AS2	8 Jun	56	19.0	52.3	61.6	73.9	86.9	3.3	3.9	4.7	5.5	15.2
AS3	15 Jun	37	23.1	51.8	59.2	72.6	107.6	2.7	4.0	4.9	5.6	12.5
AS4	22 Jun	22	37.6	55.6	59.3	64.8	110.6	2.6	4.4	4.9	5.2	7.7
AS5	29 Jun	14	44.2	48.4	54.5	62.2	68.8	4.2	4.6	5.3	6.0	6.5
AS6	6 Jul	3	35.9	38.6	42.6	64.0	78.3	3.7	4.5	6.8	7.5	8.0

Table 12. Continued.

Release	Date	N	Travel time (days) Min.	20%	Median	80%	Max.	Migration rate (km/day) Min.	20%	Median	80%	Max.
2000												
PL1	1 Jun	46	21.3	35.7	45.4	58.1	102.1	3.9	6.8	8.8	11.1	18.7
PL2	8 Jun	7	37.7	41.6	43.0	73.4	87.6	4.5	5.4	9.3	9.6	10.6
PL3	15 Jun	10	40.6	45.4	77.5	102.2	154.5	2.6	3.9	5.1	8.8	9.8
PL4	23 Jun	6	33.9	36.6	49.6	96.6	102.8	3.9	4.1	8.0	10.9	11.7
PL5	29 Jun	5	20.0	43.6	52.7	77.2	94.0	4.2	5.2	7.5	9.1	19.9
PL6	6 Jul	2	92.1	99.1	109.5	120.0	127.0	3.1	3.3	3.6	4.0	4.3
BC1	1 Jun	77	24.4	38.6	48.5	69.6	180.2	1.8	4.6	6.5	8.2	13.0
BC2	8 Jun	31	29.9	39.0	48.8	73.9	172.3	1.8	4.3	6.5	8.1	10.6
BC3	15 Jun	25	36.9	49.4	70.7	91.2	161.6	2.0	3.5	4.5	6.4	8.6
BC4	22 Jun	14	49.5	74.4	97.2	135.0	157.3	2.0	2.3	3.3	4.3	6.4
BC5	29 Jun	7	56.8	86.8	90.8	136.5	154.0	2.1	2.3	3.5	3.7	5.6
BC6	6 Jul	3	55.1	72.3	98.1	125.2	143.2	2.2	2.5	3.2	4.4	5.8
2001												
PL1	23 May	5	55.5	58.2	59.2	71.1	93.9	1.3	1.7	2.0	2.0	2.1
PL2	30 May	2	47.0	48.7	51.3	53.8	55.5	2.1	2.2	2.3	2.4	2.5
PL3	6 Jun	1	67.7	67.7	67.7	67.7	67.7	1.8	1.8	1.8	1.8	1.8
PL4	13 Jun	1	129.0	129.0	129.0	129.0	129.0	0.9	0.9	0.9	0.9	0.9
PL5	20 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PL6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
BC1	23 May	44	51.7	57.3	67.5	84.6	127.8	0.9	1.4	1.8	2.1	2.3
BC2	30 May	28	47.0	55.7	65.5	87.2	107.0	1.1	1.4	1.8	2.1	2.5
BC3	6 Jun	5	52.8	60.2	65.7	69.7	78.5	1.5	1.7	1.8	2.0	2.3
BC4	13 Jun	1	69.2	69.2	69.2	69.2	69.2	1.7	1.7	1.7	1.7	1.7
BC5	20 Jun	1	54.1	54.1	54.1	54.1	54.1	2.2	2.2	2.2	2.2	2.2
BC6	27 Jun	0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 13. Comparison of hatchery and wild subyearling chinook salmon released in the free-flowing Snake River above Lower Granite Dam, 1998-2001. LGR = Lower Granite Dam. Numbers shown are means (length and survival) or medians (travel time and passage date).

Release	Length (mm)		Travel time (days)		Passage date at LGR		Percent survival (s.e.)	
date	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild	Hatchery	Wild
1998								
5 May	-	64	-	52	-	29 Jun	-	58.7 (6.0)
12 May	-	69	-	49	-	30 Jun	-	50.6 (5.4)
19 May	-	71	-	48	-	7 Jul	-	65.2 (3.6)
26 May	-	72	-	42	-	8 Jul	-	63.6 (3.7)
2 Jun	73	76	42	40	14 Jul	12 Jul	52.4 (1.4)	60.7 (4.5)
9 Jun	73	78	36	36	16 Jul	26 Jul	51.5 (1.4)	56.7 (3.4)
16 Jun	76	80	31	39	17 Jul	26 Jul	48.3 (1.5)	48.8 (4.6)
23 Jun	74	82	37	34	31 Jul	28 Jul	25.8 (1.3)	32.3 (5.1)
30 Jun	75	87	40	40	9 Aug	9 Aug	20.7 (1.3)	20.7 (9.6)
7 Jul	78	-	37	-	13 Aug	-	23.7 (2.2)	
1999								
11 May	-	65	-	43	-	26 Jun	-	66.7 (21.9)
18 May	-	66	-	47	-	5 Jul	-	73.0 (6.5)
25 May	-	68	-	40	-	6 Jul	-	80.2 (5.5)
1 Jun	78	76	45	33	16 Jul	5 Jul	43.8 (2.1)	75.4 (3.7)
8 Jun	79	77	49	43	27 Jul	23 Jul	39.8 (1.7)	86.0 (9.2)
15 Jun	79	80	49	38	4 Aug	25 Jul	26.6 (1.4)	62.9 (5.4)
22 Jun	80	79	46	36	8 Aug	30 Jul	24.5 (1.3)	42.9 (5.5)
29 Jun	83	77	42	33	10 Aug	3 Aug	11.0 (1.0)	20.8 (8.0)
6 Jul	94	77	39	24	14 Aug	1 Aug	6.2 (1.2)	11.1 (6.0)

Table 13. Continued.

Release date	Length (mm) Hatchery	Length (mm) Wild	Travel time (days) Hatchery	Travel time (days) Wild	Passage date at LGR Hatchery	Passage date at LGR Wild	Percent survival (s.e.) Hatchery	Percent survival (s.e.) Wild
2000								
20 April	-	64	-	49	-	13 Jun	-	31.8 (5.7)
27 April	-	63	-	60	-	2 Jul	-	50.0 (13.1)
4 May	-	65	-	50	-	29 Jun	-	40.5 (6.6)
11 May	-	68	-	46	-	30 Jun	-	51.5 (6.1)
18 May	-	72	-	44	-	7 Jul	-	57.3 (5.2)
25 May	-	79	-	40	-	8 Jul	-	45.9 (3.8)
1 Jun	81	82	31	47	2 Jul	22 Jul	25.3 (1.0)	51.7 (5.5)
8 Jun	82	85	26	40	4 Jul	22 Jul	11.7 (0.8)	50.6 (7.5)
15 Jun	82	91	39	32	23 Jul	21 Jul	12.4 (0.9)	45.7 (13.5)
22 Jun	83	-	50	-	10 Aug	-	6.1 (0.6)	-
29 Jun	85	-	64	-	31 Aug	-	4.2 (0.6)	
6 Jul	86	-	59	-	2 Sep	-	2.1 (0.4)	
2001								
2 May	-	63	-	71	-	13 Jul	-	26.6 (7.5)
9 May	-	65	-	57	-	5 Jul	-	36.7 (4.8)
16 May	-	65	-	52	-	7 Jul	-	26.6 (3.4)
23 May	87	68	41	44	3 Jul	5 Jul	26.1 (1.1)	22.3 (2.6)
30 May	88	70	36	45	5 Jul	16 Jul	16.9 (0.9)	16.2 (3.8)
6 Jun	91	72	32	39	8 Jul	15 Jul	7.1 (0.8)	13.3 (3.2)
13 Jun	88	81	28	27	11 Jul	10 Jul	2.8 (0.5)	8.7 (3.9)
20 Jun	92	79	22	-	13 Jul	-	1.5 (0.4)	-
27 Jun	93	91	51	-	18 Aug	-	-	-

Table 14. Number of detections during spring 1999 and 2001 (and percentage of total number released) from hatchery fall chinook salmon released as subyearlings during 1998 and 2000, respectively. Releases in spring 1998 were made at Pittsburg Landing and Billy Creek on the Snake River and from Big Canyon Creek on the Clearwater River. Releases from spring 2000 were made from Pittsburg Landing and Billy Creek.

Release date	Big Canyon Creek	Billy Creek	Pittsburg Landing	Total
		1999		
2 Jun	2 (0.2%)	3 (0.2%)	11 (0.9%)	16 (0.4%)
9 Jun	16 (1.3%)	9 (0.7%)	21 (1.6%)	46 (1.2%)
16 Jun	22 (1.7%)	19 (1.5%)	27 (2.2%)	68 (1.8%)
23 Jun	28 (2.2%)	25 (2.0%)	16 (1.3%)	69 (1.8%)
30 Jun	40 (3.2%)	16 (1.3%)	16 (1.3%)	72 (1.9%)
7 Jul	37 (2.9%)	23 (1.8%)	NA	60 (2.3%)
All dates	145 (1.9%)	95 (1.3%)	91 (1.4%)	331 (1.5%)
		2000		
1 Jun		23 (1.9)	11 (0.9)	34 (1.4)
8 Jun		25 (2.0)	1 (0.1)	26 (1.0)
15 Jun		20 (1.6)	7 (0.6)	27 (1.1)
22 Jun		13 (1.1)	4 (0.3)	17 (0.7)
29 Jun		16 (1.3)	7 (0.6)	23 (0.9)
6 Jul		13 (1.0)	6 (0.5)	19 (0.8)
All dates		110 (1.5)	36 (0.5)	146 (1.0)

Table 15. Product-moment correlation coefficients (r) among independent variables for groups of subyearling fall chinook salmon released in the free-flowing Snake River, 1995-2001. Each variable was adjusted by subtracting respective annual mean.

			Rearing index period[1]				Migration index period[2]			
		DATE[3]	RFLOW[4]	RTEMP[5]	RTURB[6]	RTIME[7]	MFLOW[4]	MTEMP[5]	MTURB[6]	MTIME[8]
Rearing index period	RFLOW	-0.86**								
	RTEMP	0.97**	-0.85**							
	RTURB	0.78*	-0.75*	0.73*						
	RTIME	-0.20	0.09	-0.09	-0.04					
Migra-tion index period	MFLOW	-0.77*	0.91**	-0.79*	-0.69*	-0.07				
	MTEMP	0.71*	-0.66*	0.73*	0.34	0.15	-0.65*			
	MTURB	0.79*	-0.85**	0.77*	0.66*	-0.12	-0.83**	0.59		
	MTIME	0.48	-0.39	0.41	0.63	-0.44	-0.34	-0.002	0.58	

1. Period between time of release and 5th percentile of Lower Granite Dam detection distribution.
2. Period between 5th and 50th percentiles of Lower Granite Dam detection distribution.
3. Release date.
4. Mean of daily average discharge at Lower Granite Dam during index period.
5. Mean of daily average temperature at Lower Granite Dam during index period.
6. Mean of daily turbidity reading at Lower Granite Dam during index period.
7. Elapsed time between release and 5th percentile of Lower Granite Dam detection distribution.
8. Elapsed time between 5th and 50th percentiles of Lower Granite Dam detection distribution.

** $r^2 > 0.65$

* $0.40 < r^2 < 0.65$

Table 16. Product-moment correlation coefficients (r) among dependent and independent variables for groups of subyearling fall chinook salmon released in the free-flowing Snake River, 1995-2001. Each variable was adjusted by subtracting respective annual mean.

		SURV[1]	RTIME[2]	MTIME[3]	TTIME[4]
	RTIME	0.22			
	MTIME	-0.45	-0.44		
	TTIME	-0.34	0.17	0.81*	
	DATE	-0.84**	-0.20	0.48	0.40
Rearing index period	RFLOW[5]	0.83**	0.09	-0.39	-0.37
	RTEMP[6]	-0.80*	-0.09	0.41	0.39
	RTURB[7]	-0.73*	0.04	0.63	0.66
Migration index period	MFLOW[5]	0.74*	-0.07	-0.34	-0.42
	MTEMP[6]	-0.60	0.15	-0.002	0.09
	MTURB[7]	-0.70*	-0.12	0.58	0.56

1. Estimated survival from release to Lower Granite Dam.
2. Time between release and 5th percentile of Lower Granite Dam detection distribution.
3. Time between 5th and 50th percentiles of Lower Granite Dam detection distribution.
4. Time between release and 50th percentile of Lower Granite Dam detection distribution (median travel time).
5. Mean of daily average discharge at Lower Granite Dam during index period.
6. Mean of daily average temperature at Lower Granite Dam during index period.
7. Mean of daily turbidity reading at Lower Granite Dam during index period.

** $r^2 > 0.65$

* $0.40 < r^2 < 0.65$

Table 17. Product-moment correlation coefficients (*r*) among dependent and independent variables for weekly groups of subyearling fall chinook salmon leaving Lower Granite Dam, 1995-2001. Each variable was adjusted by subtracting respective annual mean.

	SURV[1]	DATE[2]	TTIME[3]	FLOW[4]	TEMP[5]	TURB[6]
SURV						
DATE	-0.59*					
TTIME	0.02	-0.15				
FLOW	0.40	-0.84**	0.07			
TEMP	-0.04	0.34	-0.06	-0.65*		
TURB	-0.20	0.46	0.01	-0.48	0.44	

1. Estimated survival from Lower Granite Dam to Lower Monumental Dam.
2. Middle date of weekly period during which fish were "released."
3. Median travel time from Lower Granite Dam to Lower Monumental Dam.
4. Mean of daily average discharge at Lower Monumental Dam during index period (period between 25th and 75th percentiles of Lower Monumental Dam detection distribution).
5. Mean of daily average temperature at Lower Monumental Dam during index period.
6. Mean of daily turbidity reading at Lower Monumental Dam during index period.

** $r^2 > 0.50$
* $0.25 < r^2 < 0.50$

Table 18. Number of fish handled (N) and mortalities during PIT tagging of river-run subyearling chinook salmon at McNary Dam for post-detection bypass survival evaluation in 2000.

	Hatchery yearlings		Unclipped yearlings		River-run subyearlings		Hatchery steelhead		Wild steelhead		Coho		Hatchery sockeye		Wild sockeye	
Date	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts
19 Jun	7	1	1	0	343	54	4	0	1	0	10	0	0	0	1	0
20 Jun	58	1	13	1	5,313	10	15	0	2	0	44	3	0	0	5	0
21 Jun	21	1	7	0	5,269	46	27	1	6	0	86	3	0	0	2	0
23 Jun	26	0	11	1	4,652	51	10	0	2	0	48	1	0	0	3	0
26 Jun	4	0	2	0	1,509	49	2	0	1	0	6	0	0	0	0	0
28 Jun	13	1	4	0	4,202	44	8	0	1	0	11	0	0	0	0	0
30 Jun	4	0	1	0	1,975	43	4	0	2	0	7	0	0	0	0	0
03 Jul	4	0	0	0	3,121	108	2	0	1	0	0	0	0	0	2	0
05 Jul	5	0	1	0	3,953	36	1	0	1	0	1	0	0	0	1	0
07 Jul	7	1	2	1	3,227	34	2	0	0	0	8	1	1	0	11	0
10 Jul	12	1	0	0	3,746	30	4	0	0	0	5	0	0	0	32	0
12 Jul	6	1	1	0	6,299	64	5	1	0	0	11	1	0	0	32	0
14 Jul	2	0	0	0	921	20	1	0	1	0	2	0	0	0	11	0
17 Jul	4	1	0	0	3,292	36	3	0	0	0	11	0	1	0	60	2
19 Jul	5	1	0	0	3,289	42	3	0	0	0	9	0	1	0	59	1
Total	178	9	43	3	51,111	667	91	2	18	0	259	9	3	0	219	3

Table 19. Conditions at McNary Dam (daily averages) during releases for juvenile bypass evaluation in 2000 and during releases for survival evaluation in 2001. There was no spill during release dates in 2001.

Date	Total discharge (kcfs)	Spill (kcfs)	Percent spill	Turbidity (Secchi disk)	Water temperature (^{0}C)
		2000			
20 Jun	200.3	63.5	31.7	4.4	16.9
21 Jun	227.2	59.4	26.1	4.4	17.0
22 Jun	206.0	38.5	18.7	3.8	17.0
23 Jun	202.5	39.4	19.5	3.8	17.1
24 Jun	192.9	28.9	15.0	3.8	16.5
25 Jun	171.4	0.0	0.0	4.3	17.3
26 Jun	173.7	0.0	0.0	3.9	16.1
27 Jun	192.7	20.2	10.5	4.1	17.7
28 Jun	231.5	66.1	28.6	4.3	17.9
29 Jun	221.4	59.4	26.8	4.0	18.0
30 Jun	182.3	16.3	8.9	4.0	18.0
01 Jul	163.8	0.0	0.0	3.8	17.9
02 Jul	156.2	0.0	0.0	3.7	18.0
03 Jul	120.5	0.0	0.0	4.2	17.9
04 Jul	147.6	0.0	0.0	4.2	18.0
05 Jul	161.2	0.0	0.0	4.1	18.0
06 Jul	195.1	28.2	14.5	4.1	17.8
07 Jul	212.2	39.6	18.7	4.1	18.0
08 Jul	200.4	32.5	16.2	4.2	18.1
09 Jul	178.3	13.5	7.6	4.2	18.0
10 Jul	163.6	0.0	0.0	3.5	18.1
11 Jul	185.4	16.1	8.7	3.8	18.4
12 Jul	169.2	0.0	0.0	4.0	18.8
13 Jul	192.3	25.4	13.2	4.1	18.9
14 Jul	193.1	20.7	10.7	3.8	18.8
15 Jul	171.3	0.0	0.0	3.8	18.1
16 Jul	132.5	0.0	0.0	4.0	19.1
17 Jul	165.6	0.0	0.0	4.1	19.1
18 Jul	171.7	0.0	0.0	4.0	19.2
19 Jul	168.2	0.0	0.0	3.7	19.5
20 Jul	167.4	0.0	0.0	3.8	19.8
21 Jul	181.1	6.8	3.8	3.7	20.0
22 Jul	157.5	7.1	4.5	3.8	19.9

Table 19. Continued.

Date	Total discharge (kcfs)	Turbidity (Secchi disk)	Water temperature (°C)
		2001	
20 Jun	125.7	5.1	17.1
21 Jun	141.8	4.8	17.3
22 Jun	145.4	4.8	16.7
23 Jun	118.0	4.8	16.8
24 Jun	102.7	5.0	16.7
25 Jun	94.9	5.0	16.9
26 Jun	133.7	5.0	17.4
27 Jun	110.0	6.0	17.2
28 Jun	125.2	5.6	16.9
29 Jun	135.3	5.5	17.5
30 Jun	111.3	5.5	18.4
01 Jul	93.1	6.2	17.5
02 Jul	112.2	6.0	18.3
03 Jul	124.0	6.0	19.1
04 Jul	104.2	6.0	19.3
05 Jul	85.0	6.0	18.3
06 Jul	85.7	6.0	19.2
07 Jul	84.3	6.0	19.3
08 Jul	66.9	5.4	19.4
09 Jul	94.8	5.4	19.8
10 Jul	97.4	6.0	20.3
11 Jul	90.3	6.0	20.5
12 Jul	72.4	6.0	20.6
13 Jul	68.9	6.0	20.8
14 Jul	83.3	6.0	20.6
15 Jul	74.2	6.0	20.1
16 Jul	78.9	6.0	20.7
17 Jul	77.3	6.0	20.6
18 Jul	99.2	6.0	20.6
19 Jul	79.2	6.0	20.5
20 Jul	86.3	6.0	20.5
21 Jul	80.2	6.0	20.1
22 Jul	70.4	6.0	20.1
23 Jul	82.8	6.0	20.7
24 Jul	95.9	6.0	20.5
25 Jul	82.4	6.0	21.2
26 Jul	85.1	6.0	21.8
27 Jul	89.1	6.0	21.6
28 Jul	79.9	6.0	21.4

Table 20. Estimated detection probabilities for run-of-the-river subyearling chinook salmon released into the gatewell of McNary Dam, 2000. Standard errors in parentheses. MCN = McNary Dam; JDA = John Day Dam.

Date at McNary Dam	Number released	McNary Dam	John Day Dam
Daily release groups			
20 Jun	1,962	1.000 (0.000)	0.064 (0.036)
21 Jun	1,984	0.987 (0.009)	0.087 (0.059)
23 Jun	1,903	0.992 (0.006)	0.118 (0.078)
26 Jun	1,915	0.989 (0.011)	NA
28 Jun	1,904	1.000 (0.000)	0.250 (0.153)
30 Jun	1,875	0.976 (0.010)	0.036 (0.035)
03 Jul	1,860	1.000 (0.000)	0.053 (0.051)
05 Jul	1,949	0.989 (0.008)	0.080 (0.054)
07 Jul	1,889	0.971 (0.011)	0.091 (0.087)
10 Jul	1,915	0.986 (0.008)	0.050 (0.049)
12 Jul	1,932	0.988 (0.008)	0.059 (0.040)
14 Jul	1,716	0.992 (0.008)	0.154 (0.100)
17 Jul	1,952	0.988 (0.009)	0.214 (0.078)
19 Jul	1,630	1.000 (0.000)	0.174 (0.079)
Release groups pooled weekly			
19 Jun-25 Jun	5,849	0.992 (0.004)	0.080 (0.029)
26 Jun-2 Jul	5,694	0.984 (0.007)	0.067 (0.037)
3 Jul-9 Jul	5,698	0.984 (0.005)	0.073 (0.035)
10 Jul-16 Jul	5,563	0.988 (0.005)	0.075 (0.032)
17 Jul-19 Jul	3,582	0.993 (0.005)	0.196 (0.056)

Table 21. Estimated detection probabilities for run-of-the-river subyearling chinook salmon released into the tailrace of McNary Dam, 2000. Standard errors in parentheses.

Date at McNary	Number released	John Day Dam
Daily release groups		
20 Jun	1,683	0.063 (0.043)
21 Jun	1,730	0.174 (0.079)
23 Jun	1,689	0.154 (0.100)
26 Jun	1,763	0.167 (0.152)
28 Jun	1,667	0.100 (0.095)
30 Jun	1,615	0.111 (0.060)
03 Jul	1,711	0.385 (0.135)
05 Jul	1,736	NA
07 Jul	1,691	0.050 (0.049)
10 Jul	1,702	0.045 (0.044)
12 Jul	1,690	0.038 (0.038)
14 Jul	1,646	0.056 (0.054)
17 Jul	1,714	0.182 (0.082)
19 Jul	1,386	0.074 (0.050)
	Release groups pooled weekly	
19 Jun-25 Jun	5,102	0.118 (0.039)
26 Jun-2 Jul	5,045	0.116 (0.049)
3 Jul-9 Jul	5,138	0.128 (0.049)
10 Jul-16 Jul	5,038	0.045 (0.026)
17 Jul-19 Jul	3,100	0.122 (0.047)

Table 22. Estimated survival probabilities for run-of-the-river subyearling chinook salmon released into the gatewell of McNary Dam, 2000. Standard errors in parentheses. 1st detection is the first detection at McNary Dam. Weighted means are arithmetic means of individual estimates weighted by corresponding estimated relative variance.

Date of detection at McNary Dam	Number released	Release to 1st detection	1st detection to John Day Dam	Release to John Day Dam
Daily release groups				
20 Jun	1,962	0.986 (0.003)	0.716 (0.393)	0.706 (0.388)
21 Jun	1,984	1.000 (0.009)	0.779 (0.522)	0.779 (0.522)
23 Jun	1,903	0.994 (0.006)	0.997 (0.659)	0.991 (0.655)
26 Jun	1,915	0.994 (0.011)	NA	NA
28 Jun	1,904	0.987 (0.003)	0.130 (0.079)	0.129 (0.078)
30 Jun	1,875	0.999 (0.010)	2.758 (2.701)	2.755 (2.698)
03 Jul	1,860	0.988 (0.003)	1.324 (1.282)	1.308 (1.268)
05 Jul	1,949	1.000 (0.008)	0.981 (0.661)	0.982 (0.661)
07 Jul	1,889	1.008 (0.010)	1.359 (1.292)	1.369 (1.302)
10 Jul	1,915	0.984 (0.008)	2.015 (1.959)	1.984 (1.927)
12 Jul	1,932	0.996 (0.008)	1.237 (0.842)	1.231 (0.839)
14 Jul	1,716	0.974 (0.008)	0.455 (0.293)	0.443 (0.286)
17 Jul	1,952	0.983 (0.009)	0.343 (0.122)	0.337 (0.120)
19 Jul	1,630	0.971 (0.004)	0.420 (0.188)	0.408 (0.182)
Release groups pooled weekly				
19 Jun-25 Jun	5,849	0.994 (0.004)	0.953 (0.343)	0.947 (0.340)
26 Jun-2 Jul	5,694	0.998 (0.006)	0.874 (0.485)	0.872 (0.484)
3 Jul-9 Jul	5,698	1.000 (0.005)	1.245 (0.597)	1.247 (0.598)
10 Jul-16 Jul	5,563	0.986 (0.005)	1.092 (0.467)	1.076 (0.460)
17 Jul-19 Jul	3,582	0.977 (0.005)	0.374 (0.104)	0.365 (0.102)
Weighted mean		**0.991 (0.004)**	**0.784 (0.169)**	**0.778 (0.170)**

Table 23. Estimated survival probabilities for run-of-the-river subyearling chinook salmon released into the tailrace of McNary Dam, 2000. Standard errors in parentheses. Weighted mean is arithmetic mean of individual estimates weighted by corresponding estimated relative variance.

Date of detection at McNary Dam	Number released	Release to John Day Dam
Daily release groups		
20 Jun	1,683	0.637 (0.430)
21 Jun	1,730	0.372 (0.167)
23 Jun	1,689	0.681 (0.441)
26 Jun	1,763	0.330 (0.300)
28 Jun	1,667	0.420 (0.396)
30 Jun	1,615	0.858 (0.463)
03 Jul	1,711	0.167 (0.058)
05 Jul	1,736	NA
07 Jul	1,691	2.388 (2.322)
10 Jul	1,702	2.391 (2.330)
12 Jul	1,690	2.399 (2.345)
14 Jul	1,646	1.213 (1.173)
17 Jul	1,714	0.433 (0.193)
19 Jul	1,386	0.964 (0.649)
Release groups pooled weekly		
19 Jun-25 Jun	5,102	0.593 (0.195)
26 Jun-2 Jul	5,045	0.547 (0.228)
3 Jul-9 Jul	5,138	0.675 (0.256)
10 Jul-16 Jul	5,038	1.974 (1.108)
17 Jul-19 Jul	3,100	0.616 (0.233)
Weighted mean		**0.744 (0.205)**

Table 24. Ratios of estimated survival to John Day Dam for paired release groups of run-of-the-river subyearling chinook salmon released at McNary Dam, 2000. Weighted mean is geometric mean of individual estimates weighted by corresponding estimated relative variance.

Date at McNary	Ratio of survival estimates	Standard error
19 Jun-25 Jun	1.596	4.536
26 Jun-2 Jul	1.594	4.049
3 Jul-9 Jul	1.847	4.363
10 Jul-16 Jul	0.545	0.956
17 Jul-19 Jul	0.592	2.225
Weighted mean	**1.007**	**0.388**

Table 25. Number of fish handled (N) and mortalities during PIT tagging of river-run subyearling chinook salmon at McNary Dam for survival evaluation in 2001.

	Hatchery yearlings		Unclipped yearlings		River-run subyearlings		Hatchery steelhead		Wild steelhead		Coho		Hatchery sockeye		Wild sockeye	
Date	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts	N	Morts
19 Jun	1,187	14	58	5	5,754	81	246	7	154	3	238	1	0	0	59	2
21 Jun	101	1	2	0	2,078	3	24	1	10	0	46	0	0	0	9	0
25 Jun	25	0	0	0	6,572	17	3	0	3	0	1	0	0	0	1	0
27 Jun	9	0	1	0	1,586	11	4	0	1	1	1	0	0	0	2	0
29 Jun	16	1	0	0	1,087	6	1	0	1	1	2	0	0	0	1	0
03 Jul	5	0	1	0	1,856	9	1	0	0	0	1	0	0	0	0	0
05 Jul	12	0	0	0	1,184	12	2	0	2	0	2	0	0	0	0	0
09 Jul	145	2	13	0	2,969	31	22	0	13	0	18	0	0	0	4	0
11 Jul	201	6	14	2	7,404	297	41	2	11	0	28	0	0	0	7	0
13 Jul	38	2	3	0	5,132	228	0	0	0	0	8	1	0	0	3	0
17 Jul	37	0	0	0	5,854	142	3	0	1	0	2	0	0	0	3	1
19 Jul	9	0	1	0	2,819	46	1	0	0	0	0	0	0	0	0	0
23 Jul	12	1	3	0	3,995	42	3	0	3	1	2	0	0	0	1	0
25 Jul	12	0	3	0	7,128	141	7	0	0	0	10	1	0	0	4	0
27 Jul	10	1	1	0	3,899	66	3	0	0	0	5	0	0	0	2	0
Total	1,819	28	100	7	59,317	1,132	361	10	199	6	364	3	0	0	96	3

Table 26. Estimated survival and detection probabilities for run-of-the-river subyearling chinook salmon released into the tailrace of McNary Dam, 2001. Standard errors in parentheses. Weighted mean is arithmetic mean of individual estimates weighted by corresponding estimated relative variance.

McNary Dam release date	Number released	Survival from McNary to John Day Dam	Detection at John Day Dam
20 Jun	4,285	0.572 (0.031)	0.486 (0.028)
22 Jun	1,804	0.572 (0.049)	0.475 (0.042)
26 Jun	2,485	0.533 (0.056)	0.434 (0.047)
28 Jun	2,629	0.555 (0.059)	0.417 (0.046)
30 Jun	2,397	0.602 (0.074)	0.396 (0.050)
04 Jul	2,434	0.528 (0.107)	0.366 (0.075)
06 Jul	1,380	0.514 (0.110)	0.382 (0.083)
10 Jul	1,925	0.601 (0.086)	0.448 (0.065)
12 Jul	2,508	0.849 (0.143)	0.296 (0.051)
14 Jul	2,502	0.566 (0.067)	0.457 (0.055)
18 Jul	2,961	0.597 (0.067)	0.442 (0.051)
20 Jul	2,742	0.574 (0.068)	0.457 (0.055)
24 Jul	2,790	0.558 (0.075)	0.395 (0.054)
26 Jul	3,144	0.736 (0.110)	0.309 (0.047)
28 Jul	2,560	0.489 (0.071)	0.382 (0.056)
Weighted mean		**0.581 (0.016)**	

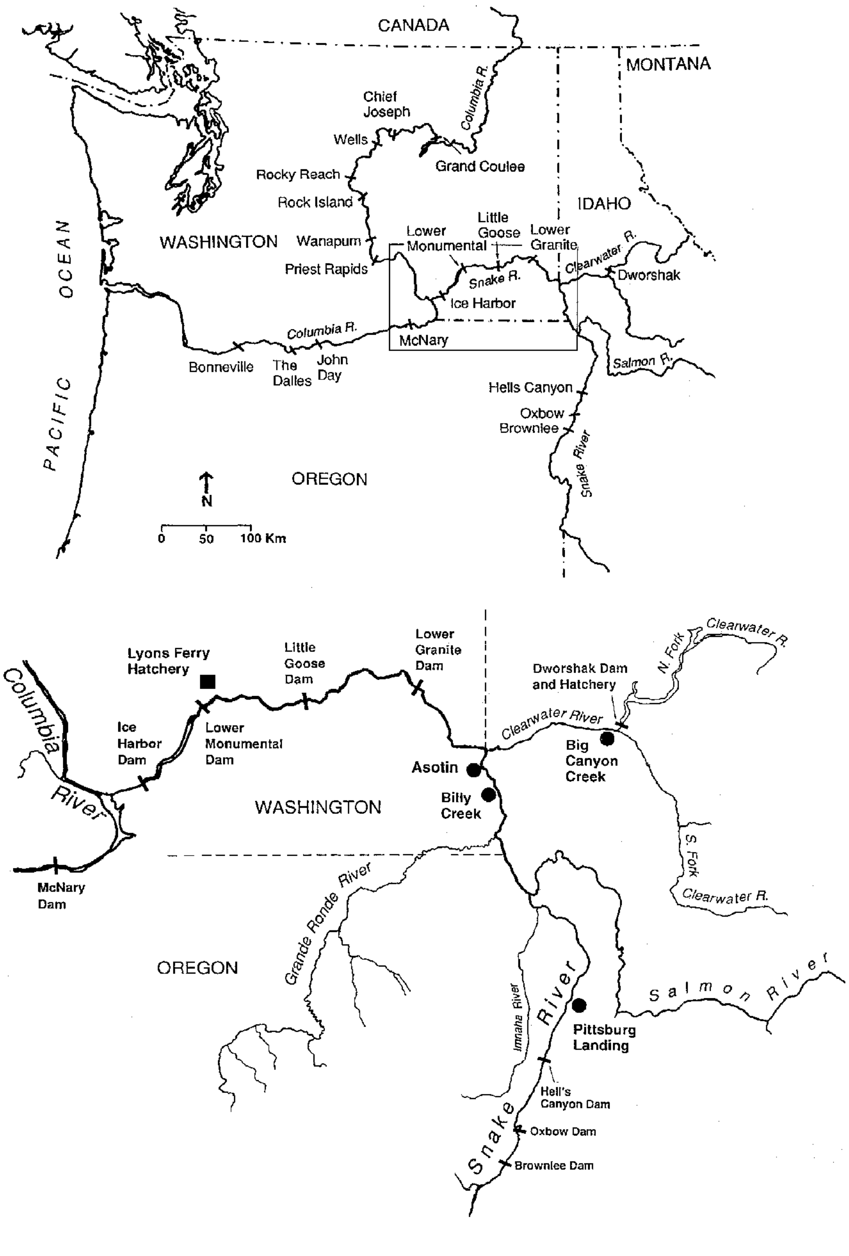

Figure 1. Study area showing location of Lyons Ferry Hatchery; release sites at Pittsburg Landing, Billy Creek, Asotin, and Big Canyon Creek; and dams with PIT-tag detection capabilities for hatchery fall chinook salmon studies, 1995-2001.

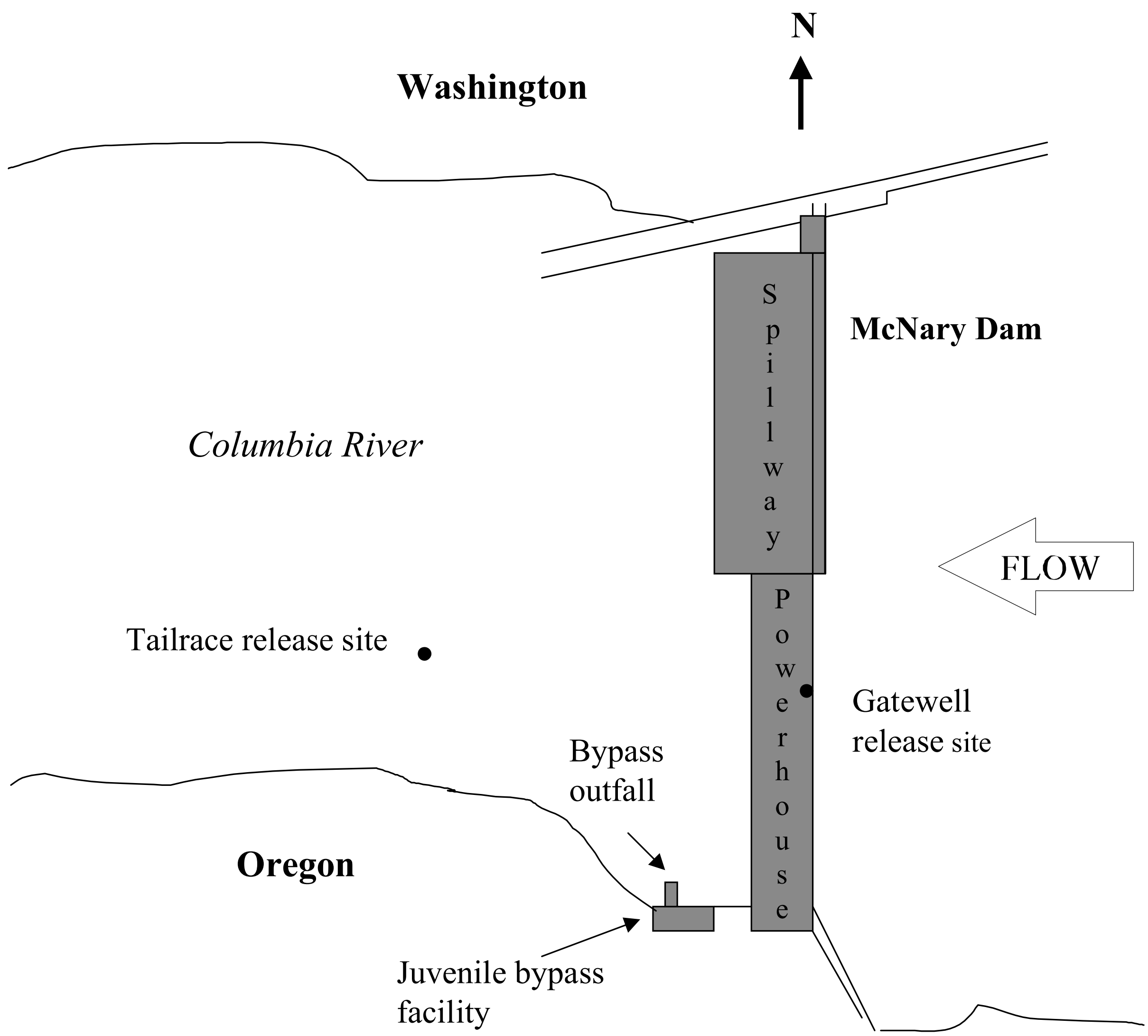

Figure 2. Diagram of McNary Dam showing locations of gatewell release site, bypass outfall, and tailrace release site.

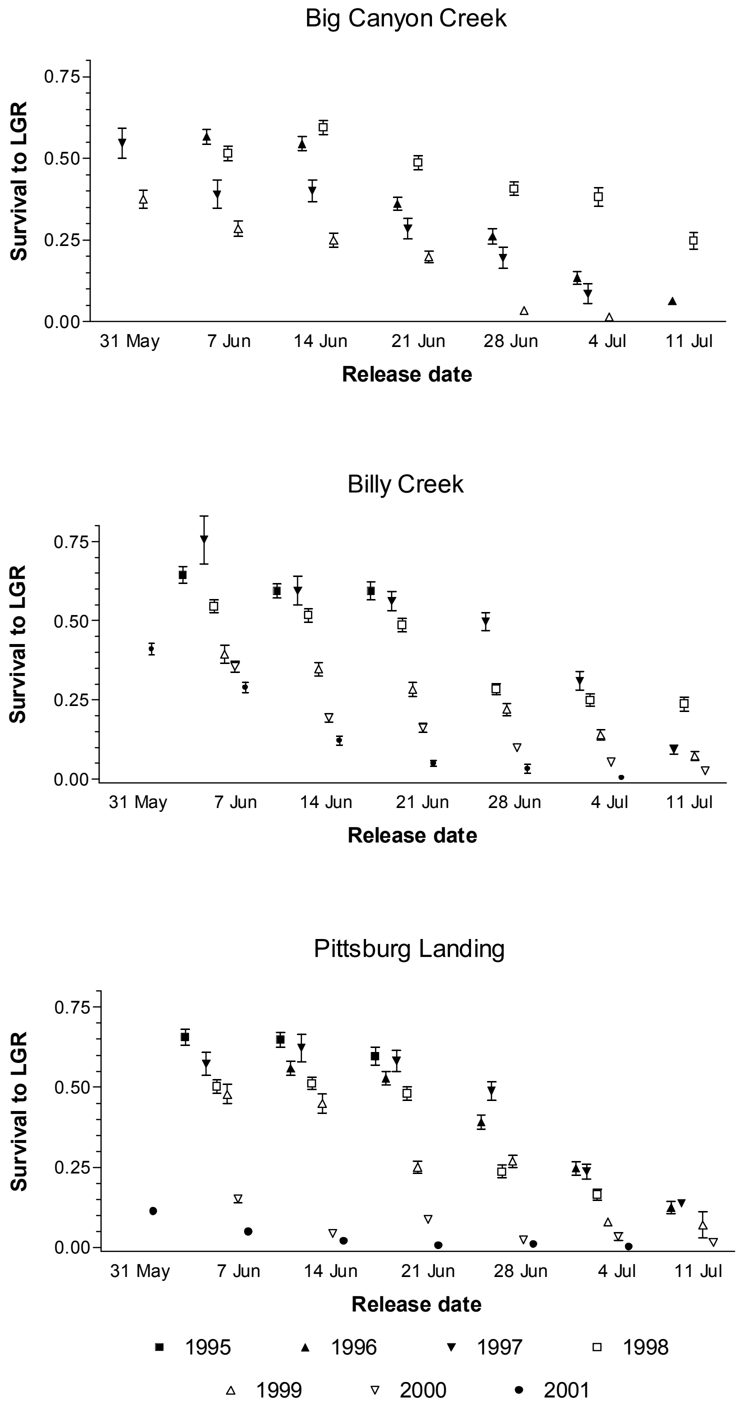

Figure 3. Estimated survival probabilities (with standard errors) from point of release in the Snake (Pittsburg Landing, Billy Creek, and Asotin) and Clearwater (Big Canyon Creek) Rivers to the tailrace of Lower Granite Dam (LGR) for PIT-tagged hatchery fall chinook salmon, 1995-2001. Groups released from Asotin in 1995 and 1999 are included with Billy Creek groups.

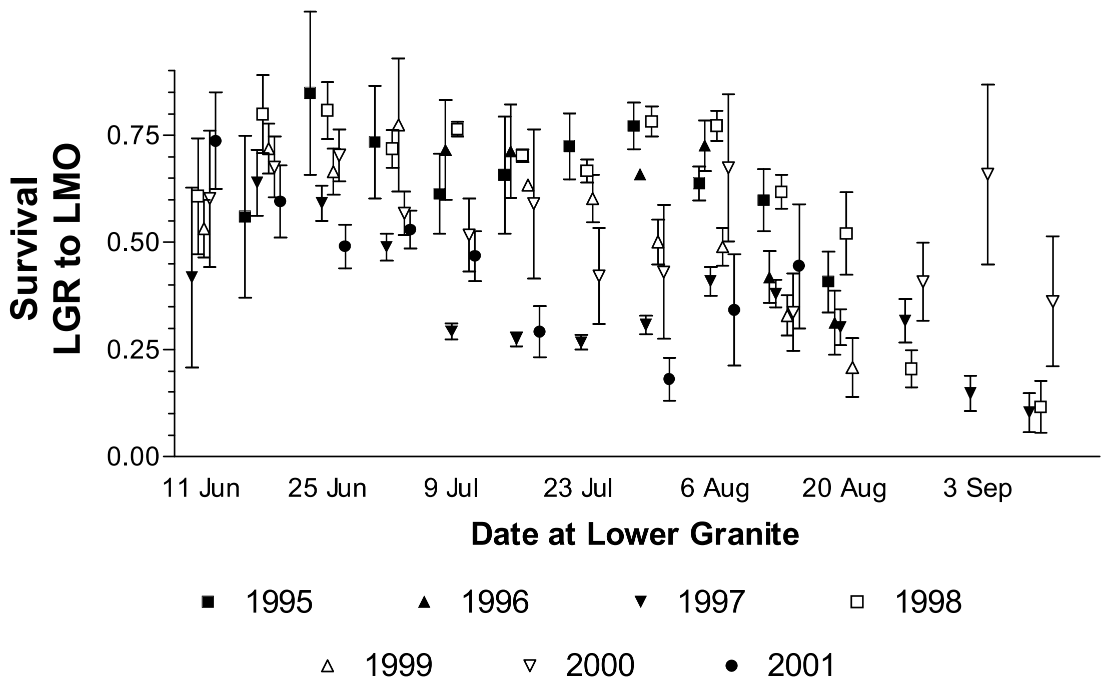

Figure 4. Estimated survival probabilities (with standard errors) to the tailrace of Lower Monumental Dam (LMO) for PIT-tagged hatchery fall chinook salmon leaving Lower Granite Dam (LGR) each week (two dams and reservoirs), 1995-2001.

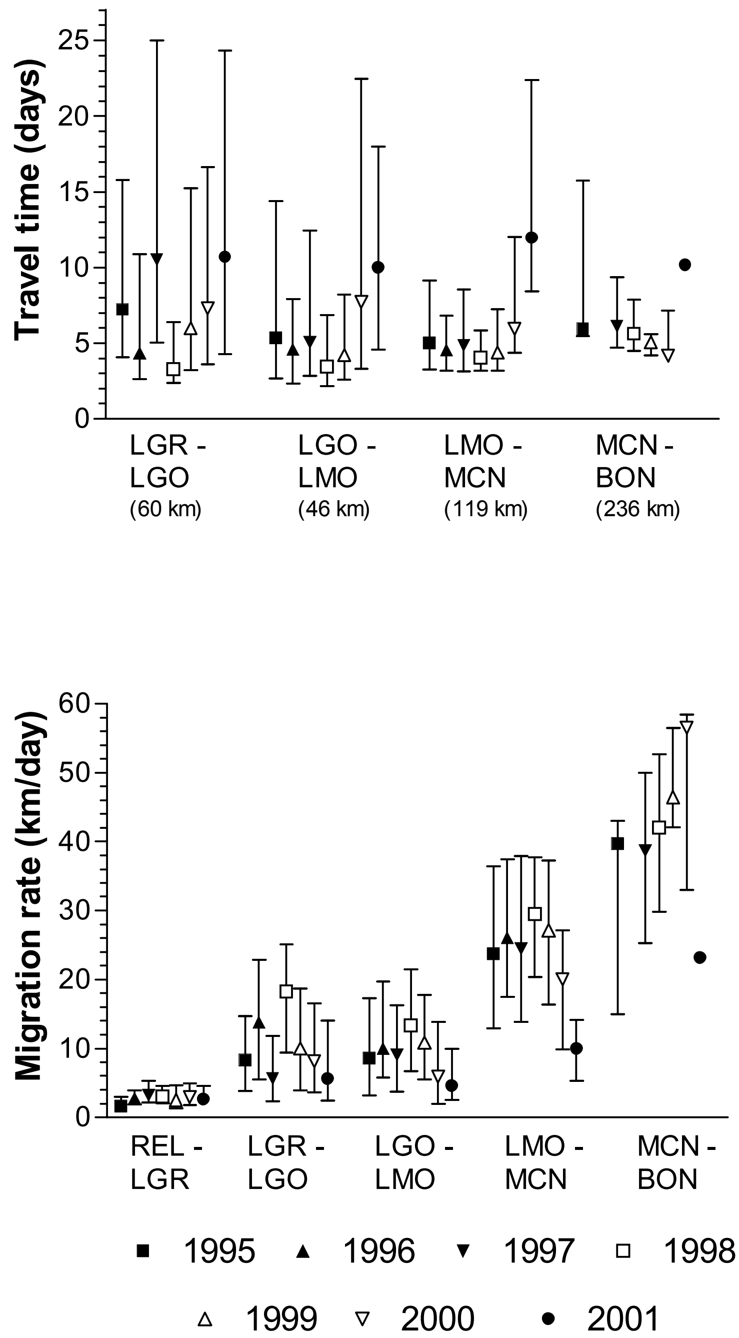

Figure 5. Median travel times (days) and migration rates (km/day) (with 20th and 80th percentiles) for PIT-tagged hatchery fall chinook salmon released in the Snake River, 1995-2001. Abbreviations: LGR-Lower Granite Dam; LGO-Little Goose Dam; LMO-Lower Monumental Dam; MCN- McNary Dam; BON-Bonneville Dam.

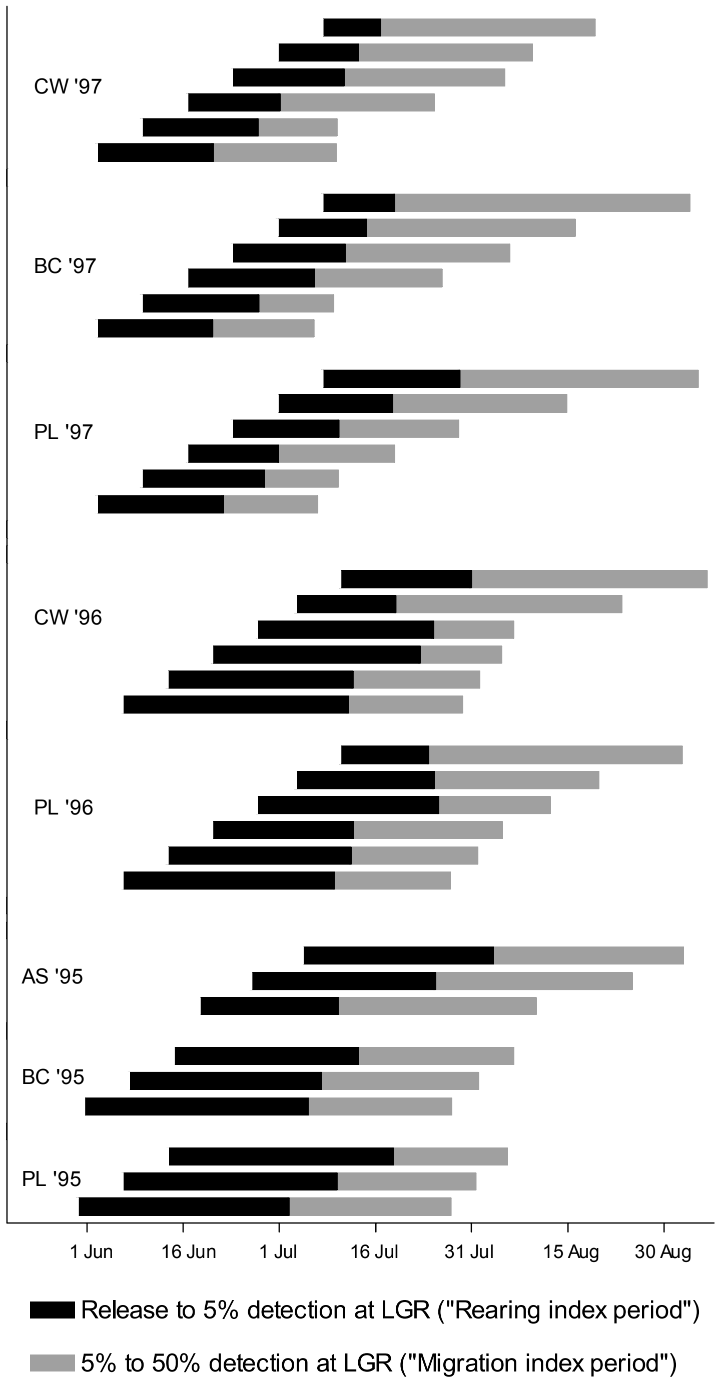

Figure 6. Release dates, dates of 5th and 50th percentiles of detection distribution at Lower Granite Dam for groups of PIT-tagged hatchery fall chinook salmon released above Lower Granite Dam, 1995-2001. Abbreviations: CW-Big Canyon Creek; BC-Billy Creek; PL-Piottsburg Landing; AS-Asotin.

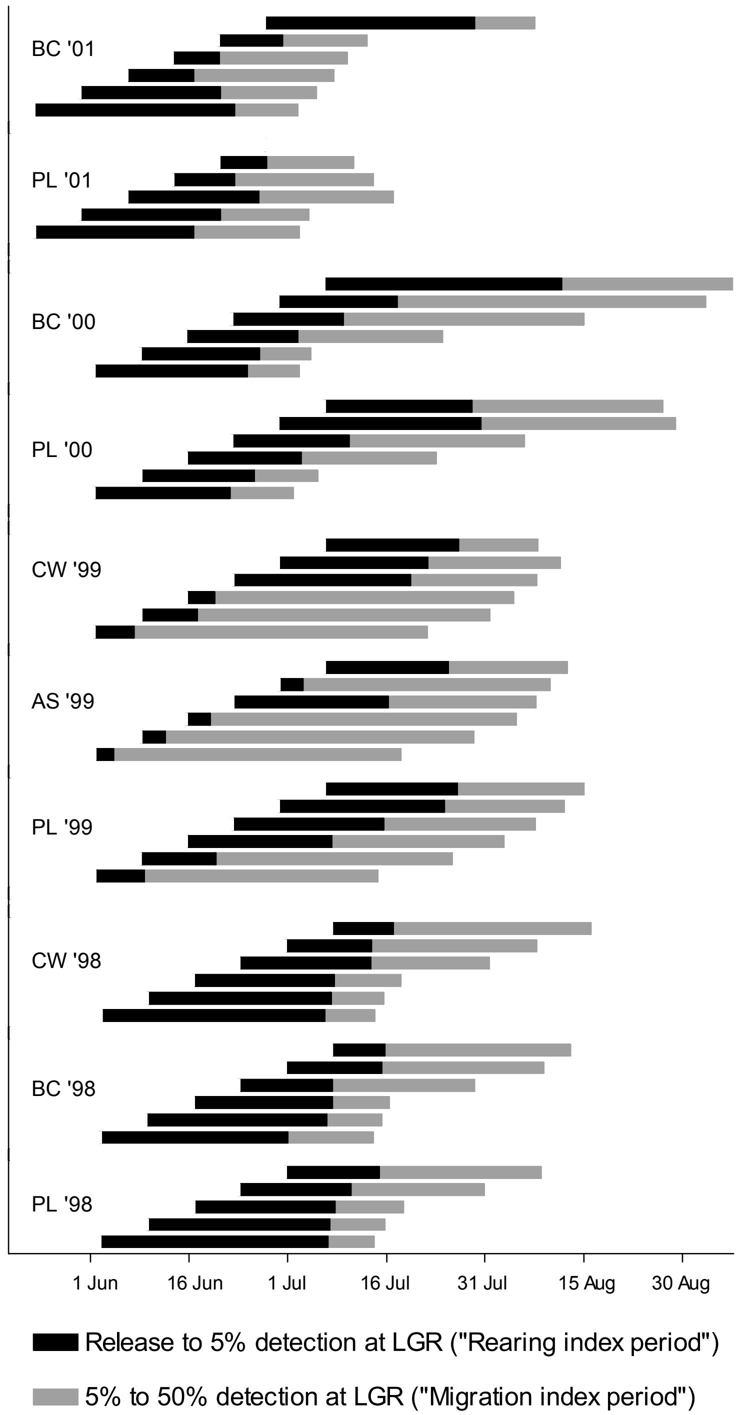

Figure 6. Continued.

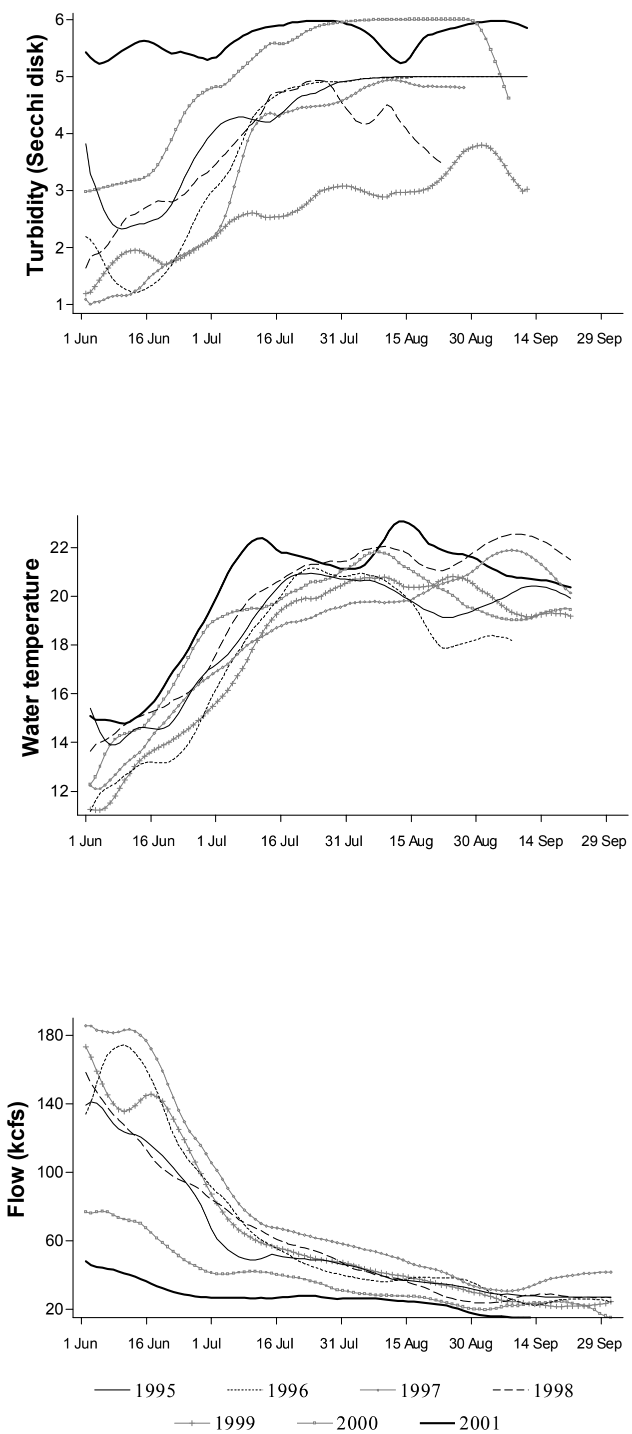

Figure 7. Environmental variables measured at Lower Granite Dam June through September, 1995-2001. Lowess smoothing used to increase legibility.

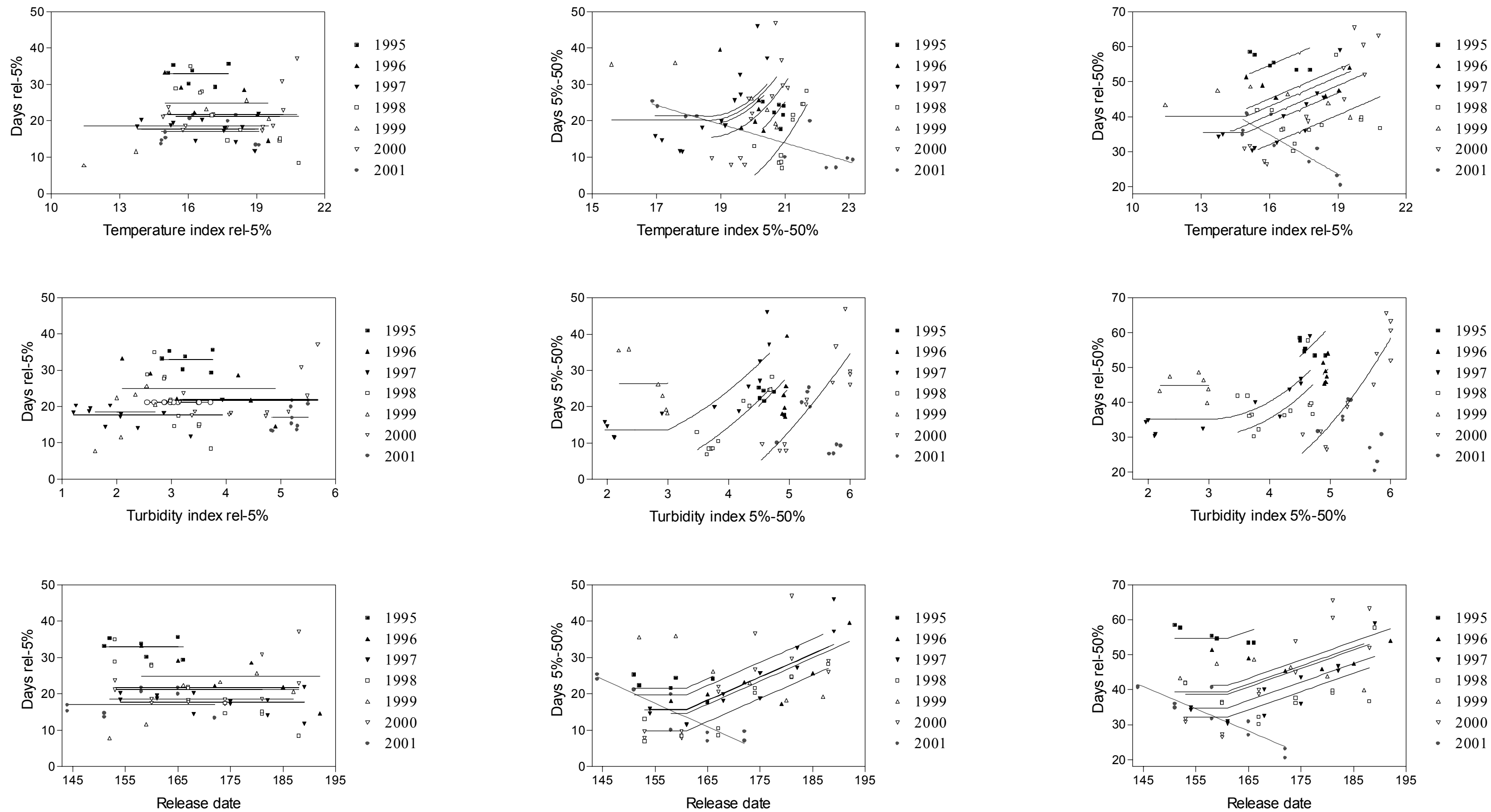

Figure 8. Relations of length of rearing period, length of migration period, and median total travel time to Lower Granite Dam with indices of flow, temperature, and turbidity exposure, and with release date for groups of PIT-tagged hatchery fall chinook salmon released at Pittsburg Landing and Billy Creek on the free-flowing Snake River, 1995-2001. Selected fitted regression models depicted with lines.

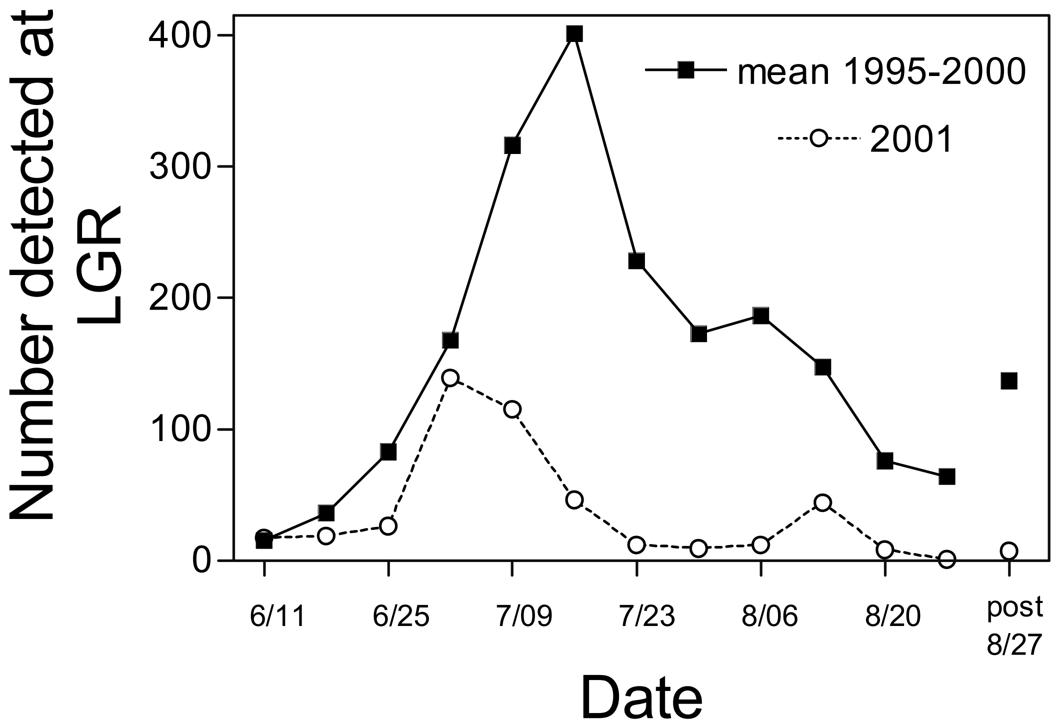

Figure 9. Weekly total detections for the second through sixth Pittsburg Landing and Billy Creek release groups in 2001 and the weekly average for groups with comparable dates in previous years. Total release sizes are nearly equal.

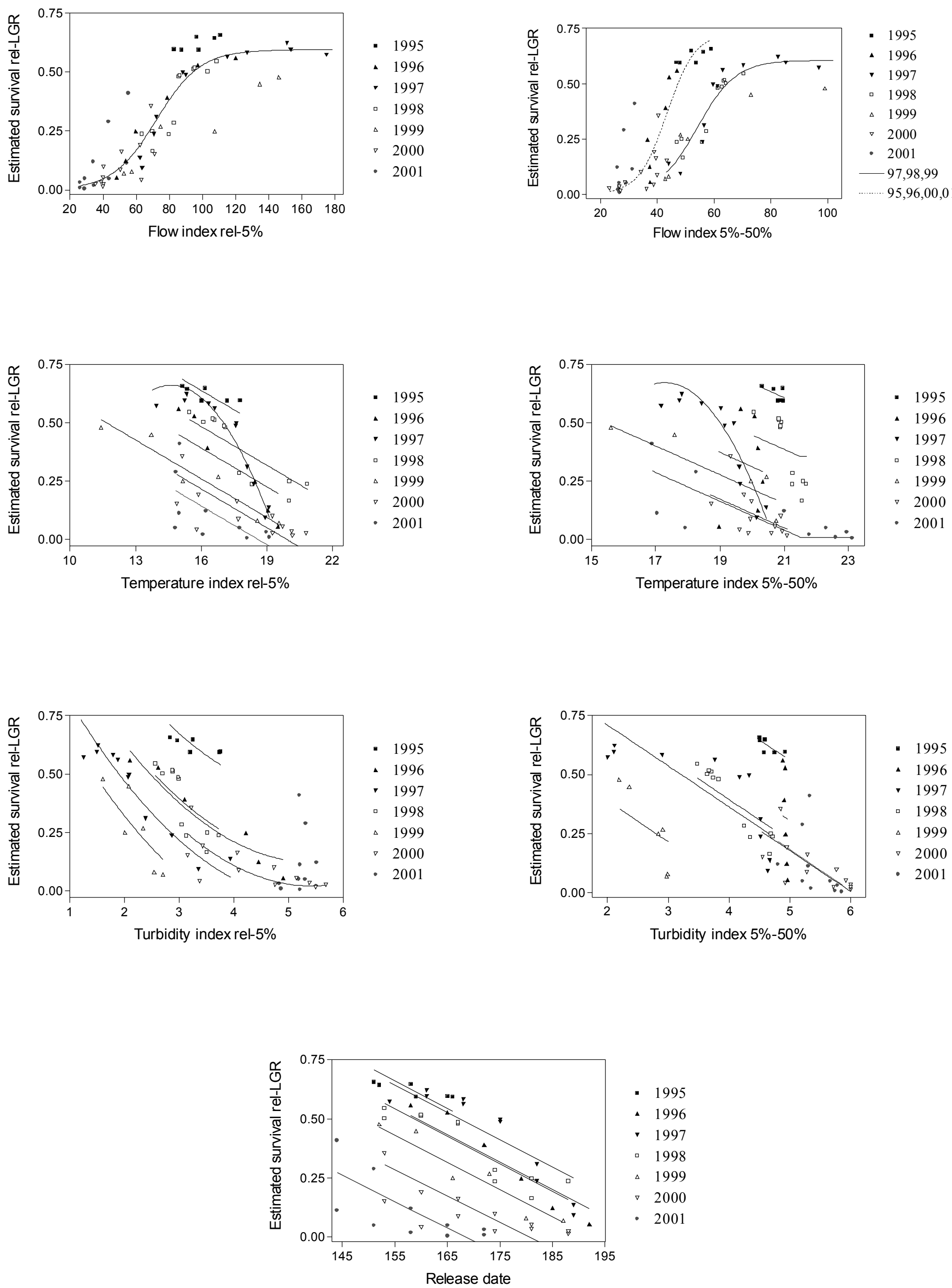

Figure 10. Relations of estimated probability of survival to Lower Granite Dam with indices of flow, temperature, and turbidity exposure, and with release date for groups of PIT-tagged hatchery fall chinook salmon released at Pittsburg Landing and Billy Creek on the free-flowing Snake River, 1995-2001. Fitted regression models depicted with lines.

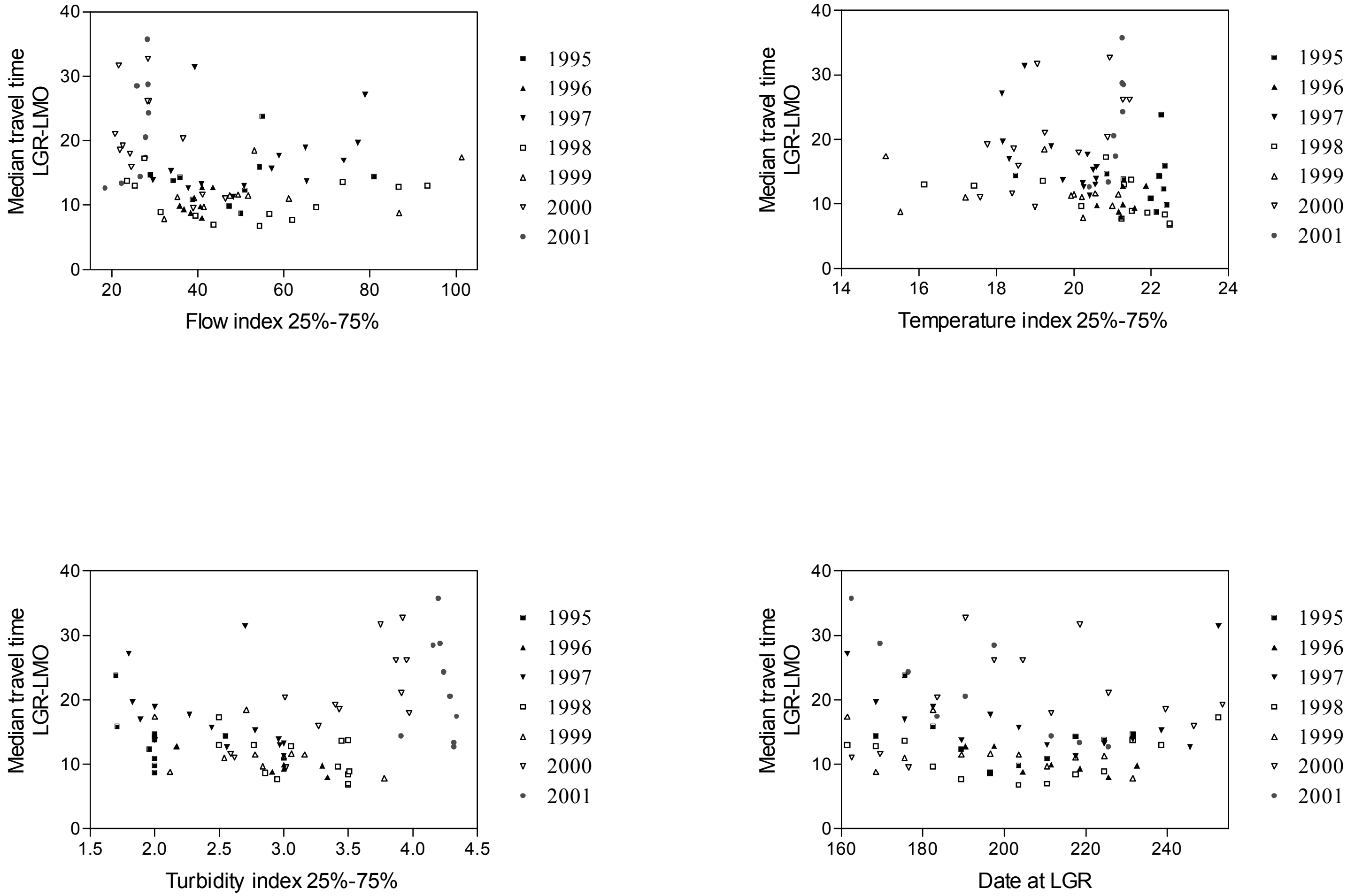

Figure 11. Relations of median travel time to Lower Monumental Dam with indices of flow, temperature, turbidity, and release date for weekly groups of PIT-tagged hatchery fall chinook salmon leaving Lower Granite Dam, 1995-2001.

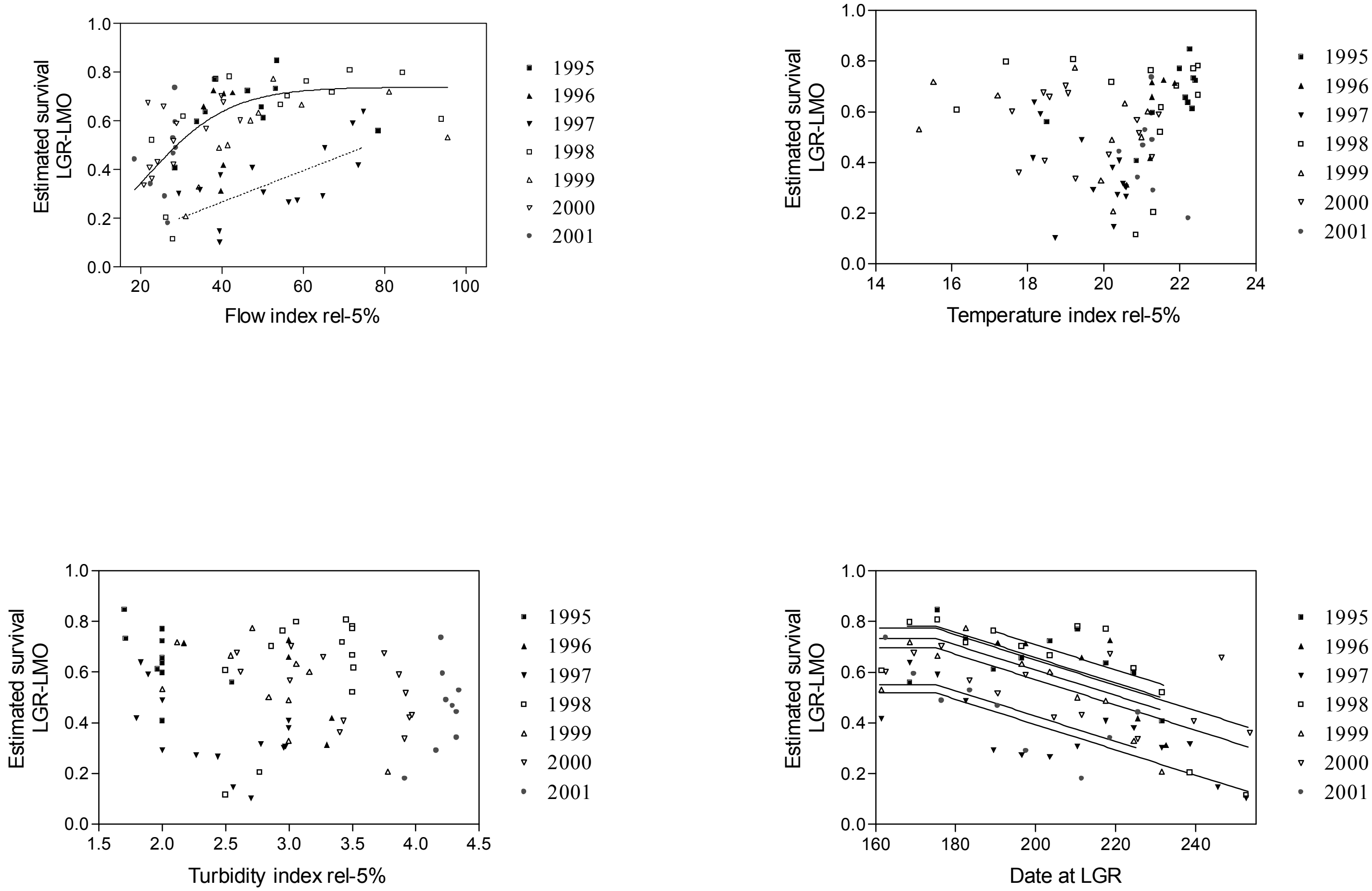

Figure 12. Relations of estimated probability of survival to Lower Monumental Dam with indices of flow, temperature, and turbidity, and release date for weekly groups of PIT-tagged hatchery fall chinook salmon leaving Lower Granite Dam, 1995-2001. Flow index shows regression line fitted to 1997 data and curve fitted to data from all other years.

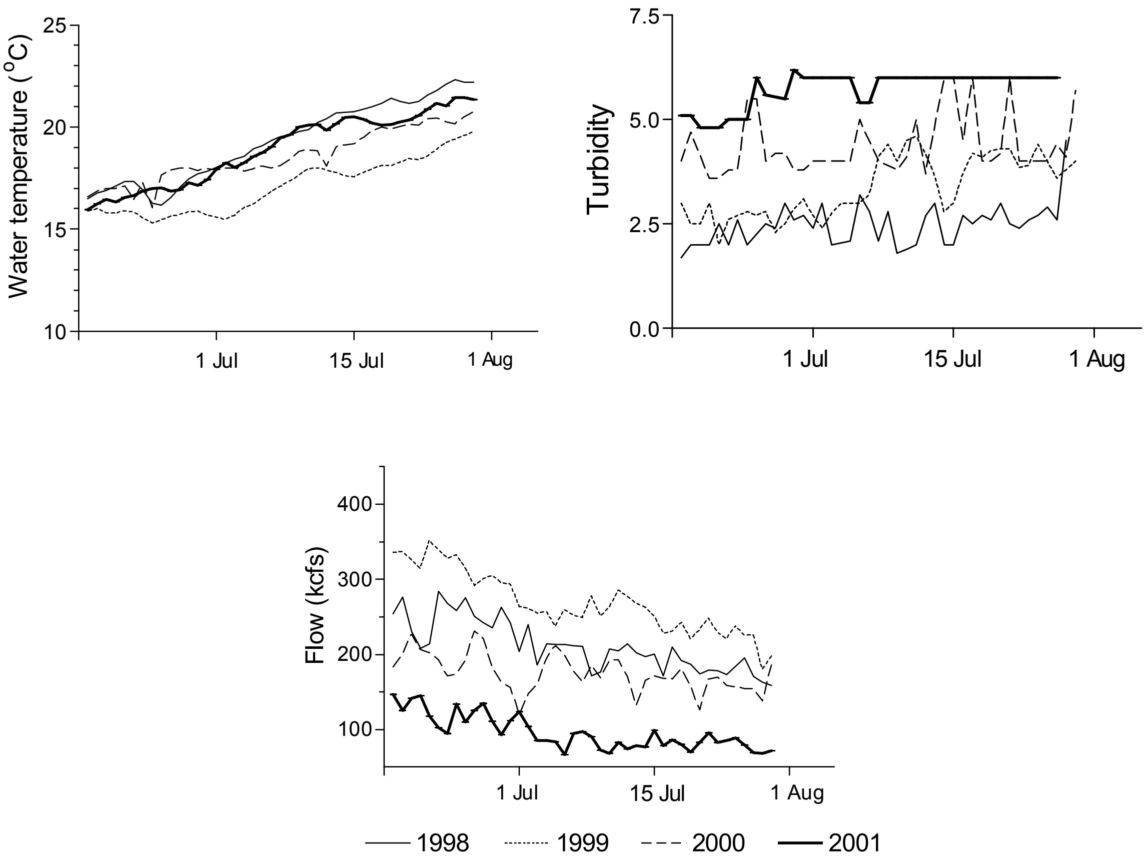

Figure 13. Environmental conditions at McNary Dam during the summer migration, 1998-2001.

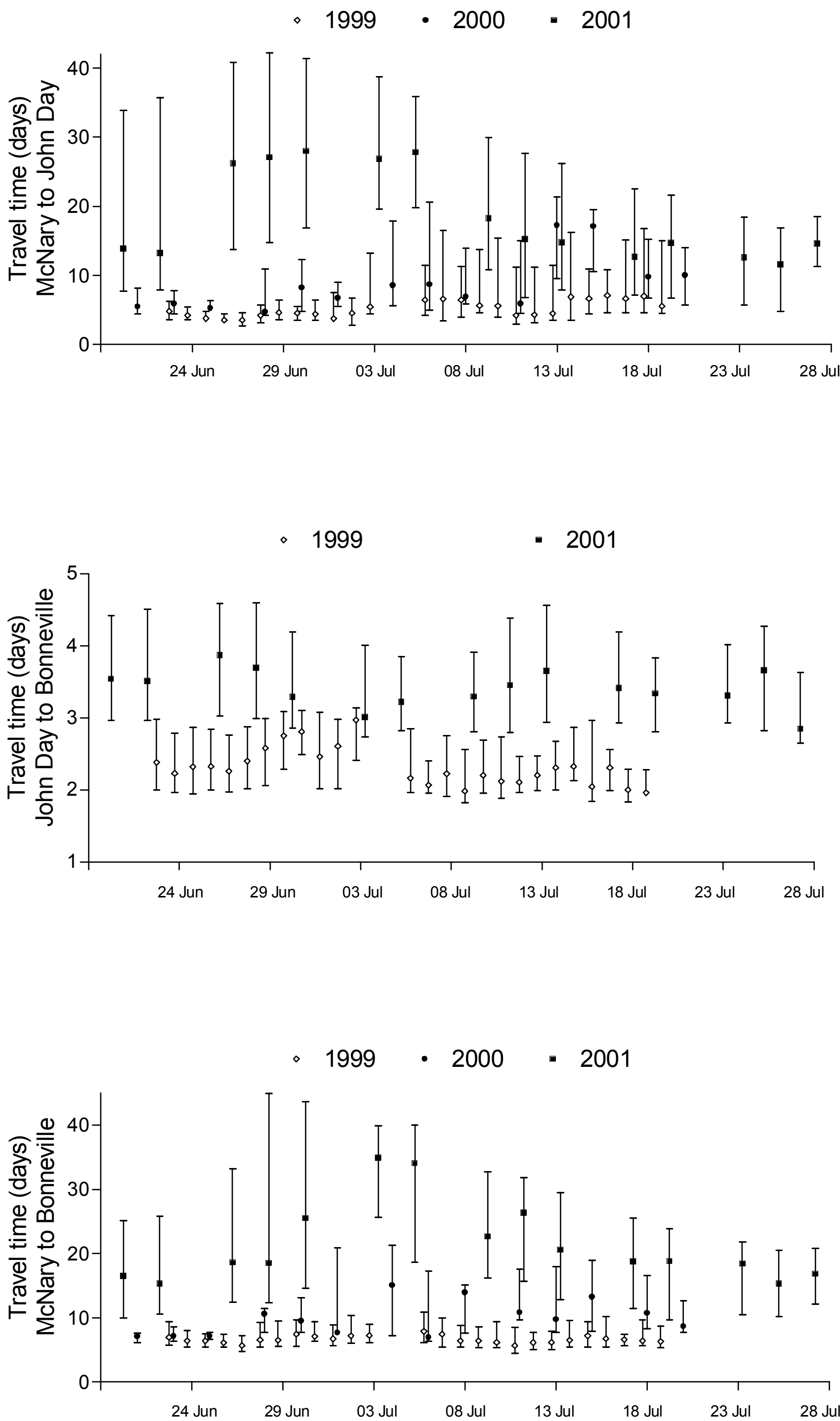

Figure 14. Median travel times (days) (with 20th and 80th percentiles) for PIT-tagged subyearling fall chinook salmon released in McNary Dam tailrace, 1999-2001.

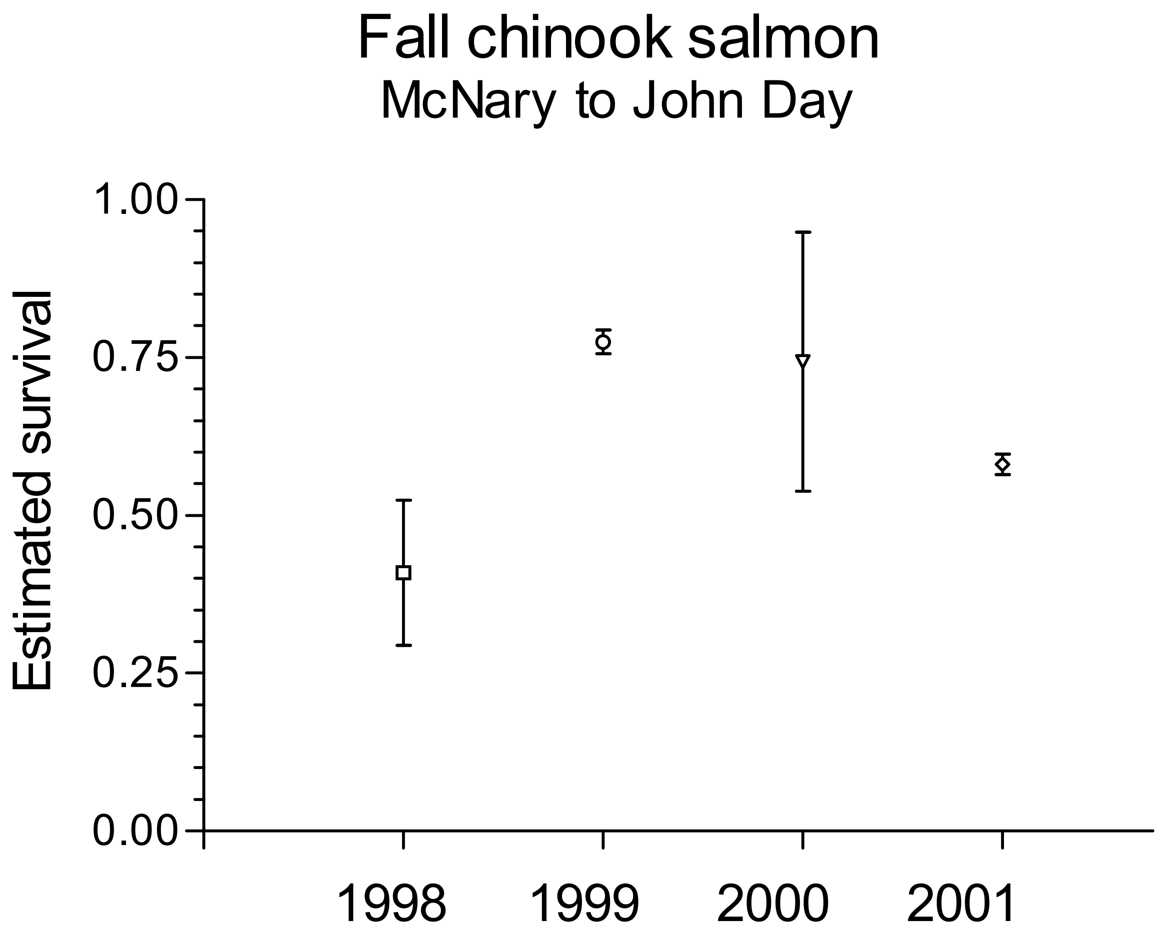

Figure 15. Annual average estimated survival for PIT-tagged subyearling fall chinook salmon from the tailrace of McNary Dam to the tailrace of John Day Dam, 1998-2001. Standard errors are also shown.

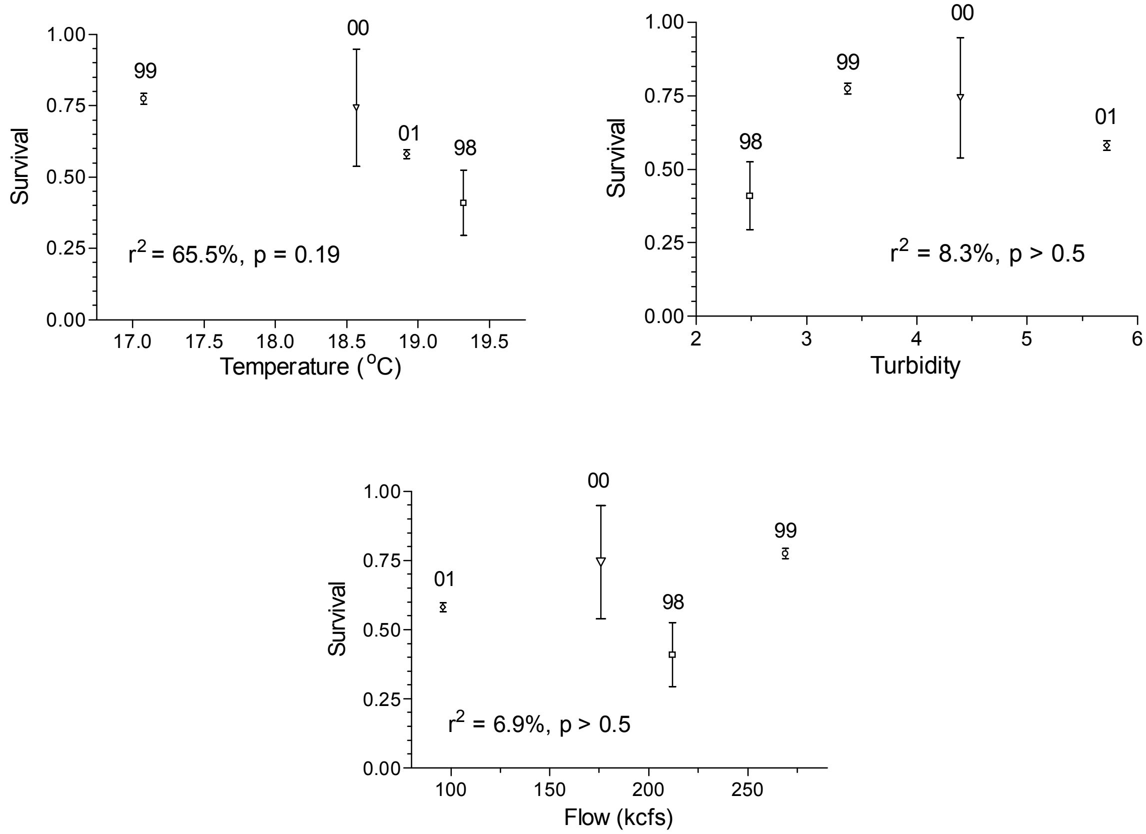

Figure 16. Annual average estimated survival for PIT-tagged subyearling fall chinook salmon from the tailrace of McNary Dam to the tailrace of John Day Dam plotted against average environmental conditions, 1998-2001.